# THE FUNDAMENTALS OF PSYCHOLOGY

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# THE FUNDAMENTALS OF PSYCHOLOGY


BY

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# PREFACE TO THE REVISED EDITION

In the present revision I have made numerous changes in expression, have modified several sections that proved unnecessarily difficult for students, and have brought the subject matter up to date. The major changes consist in the introduction of three entirely new chapters. One of these considers the differences in individuals at birth, and presents the methods of measuring intelligence, and the hereditary conditioning of intelligence. This chapter also gives a preliminary discussion of the laws of learning. To complete the discussion of the innate differences, the chapter on Instinct has been brought forward from the latter part of the book. The two other new chapters discuss respectively Imagination and Dreams, with some reference to Freud, and Fatigue and Sleep.

In the revision I have been much aided by suggestions from teachers in many institutions who have used the book, and especially by my colleagues and Dr. A. H. Sutherland. I desire to express my thanks to all of them named and unnamed.

W. B. PILLSBURY.

Ann Arbor, Michigan,
August, 1922.

# PREFACE TO THE FIRST EDITION

This book is intended to fill a gap which exists to-day between the smaller texts and the reference hand-books. I have had in mind the needs of one of my own classes which devotes a year to psychology and includes students who have had no previous work in the subject. They have more than time to cover the present texts but are lost in the details of the larger works, particularly in connection with the nervous system, sensation, and perception.

I have written for the student primarily and have not presupposed any preliminary knowledge. I have particularly avoided reference to current theories before they are explained and have indulged in no arguments on controversial matter for the benefit of colleagues rather than of the student. Opposing theories are discussed only as they may illumine statements of fact or where they have great historical importance and then only if the problem is real but is not settled.

The technical psychologist may miss long discussions of general method and points of view. I have replaced them by fuller statements of the results of experiment and more detailed treatment of the generally accepted body of facts. I have drawn upon the work of all schools without reference to the theories that the workers held, and have stated the results in terms that seemed most suitable to the particular material. Sensation and perception are discussed in structural terms, action of all sorts in behavioristic terms. This gives some inconsistencies, but they are preferable to the

awkward phrases that would result from using the terminology of any school to the exclusion of the others.

My own theory inclines towards a functionalism. The book is more concerned with what consciousness does than with what it is. As opposed to the extreme behaviorism, however, I am not concerned alone with understanding the movements of the organism and the function of the movements, but also with understanding knowledge and the way in which it develops. It is my belief that the content of the science is the same whatever the point of view from which the subject be approached, and that this content is essential and changes slowly and then through growth. The theories are less important and likely to change from decade to decade. In contrast with some of the recent authors I have endeavored to supply the content and, while I have stated my own theories in some detail, have attempted to be sufficiently undogmatic to give the instructor opportunity to develop his own point of view.

I take pleasure in acknowledging the help that has been given in the preparation of the manuscript by Dr. Adams, Miss Perkins, and my wife. All have read the manuscript or portions of it and have made numerous suggestions. The latter has also aided with proofs and index. Dr. Huber has aided much in the selection of illustrations for the neurological portions, and at his suggestion Mr. Atwell of his laboratory has drawn sections for Figures 19, 21, 23, 24, 25, and 26. I express my gratitude to both.

I also desire to thank the individuals and publishers who have permitted me to reproduce cuts: Professor Jennings for cuts from his "Behavior of Lower Organisms," Dr. Barker for illustrations from his "Nervous System," W. B. Saunders & Co. for figures from Howell's "Text-book of Physiology" and Huber's "Histology," to Rebmann Bros.

for cuts from Bing's "Regional Diagnosis," and to The Macmillan Co. for cuts from Titchener's "Text-book of Psychology," from Thorndike's "Animal Mind," and Foster's "Physiology."

W. B. PILLSBURY.

ANN ARBOR, MICHIGAN,
April 25, 1916.

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# FUNDAMENTALS OF PSYCHOLOGY

## CHAPTER I

### INTRODUCTION

It is easier to say what psychology discusses and to point out the ends of its discussions than to give a formal definition. Psychology is the science which deals with the activities commonly known as mental, the processes of perceiving, of remembering, of thinking, and particularly with the acts of the individual. As in any other science, the aim is first to determine what these activities are, what they do, and then to trace them to their conditions, to understand them in the light of every fact that can have any bearing upon them. It is easier to show what psychology is and what its aims are by concrete illustration than by abstract statements.

Take memory, for example. Psychology is concerned with knowing all that is possible of how we learn and remember. Every one is familiar with memory in a purely objective way. A lesson is studied and, when occasion arises, much of it can be repeated. How one remembers, troubles the ordinary individual very little. When questioned he knows almost as little of how he remembers as does the questioner. The task of psychology is to discover the laws and conditions of learning and recall in all of their details. It must know what methods lead most certainly

and quickly to a first learning, what kind of learning will permit retention for the longest time, and how forgetting takes place. These investigations have been carried out in great detail, as will be seen in a later chapter. While memory itself is regarded as a mental process, the measurements of memory are as objective as are measurements of the strength of materials, although of course the variation is greater from measurement to measurement. The experiments require somewhat complicated special apparatus and a special training in manipulation, and the methods used and the results obtained may be stated in terms that make no mention of mind. Thus, the most satisfactory rate for retention, the best method of distributing the repetitions, the rate of forgetting, are determined by objective tests that hold irrespective of theory. It is also possible to study very many of the conditions of recall by objective methods. One may speak a word and then ask the observer to speak the first word that occurs to him. A study of the connection between these words permits a statement in a perfectly objective way of the laws that hold for recall. These are the facts with which psychology must deal. They may be collected in much the same way for each of the different activities of man.

## The Nature of Psychology

**Methods of Psychology.** — This purely objective and experimental study of mental activities depends upon observation. It may be carried on for man in exactly the same way as for animals, by making experiments from the outside, with no attempt to discover directly what has been going on within the individual. But this is not the only method of psychology. We may also make use of the individual's report on the processes. He can observe from

within what accompanies and precedes the activities objectively measured. This, the process of self-observation or introspection, will in many cases supplement the results of direct observation, and the individual who is experimented upon can often supply an explanation when the observer can find none. While the fundamental causes of most mental phenomena are as much hidden from him as from the experimenter, he can add an account of accompanying phenomena that is nearly always suggestive, and may at times furnish a solution for the questions raised by the objective results. The two methods of psychology, then, are observation and introspection. One gives the phenomena as they present themselves to the onlooker, the other as they appear to the individual investigated. At present both methods are used under experimental conditions that make it possible to control the stimuli and to provide means of measuring many reactions that would escape either unaided observation or introspection.

**The Definition of Psychology.** — While practically all are agreed as to the field which psychology is to study and on most of the results obtained, there is and always has been much controversy over what it is that is studied. Three definitions are current at present which differ in the statement of the object to be studied:

> The first asserts that psychology is the science of mind, a direct translation of the original Greek. Two meanings are given to the word 'mind.' One regards it as something substantial, an actual thing or an actual force which produces certain effects or manifests itself in the phenomena we directly experience; the other, of more recent development, asserts that mind is just these manifestations, the sum of mental states without any assumption as to what it is that produces them.

A second definition makes psychology the science of consciousness. Consciousness, like mind in its second definition, is just the series of mental phenomena, the memories, thoughts perceptions, emotions and feelings as they are immediately experienced.

A third definition, most recent of all, defines psychology as the science of behavior. By behavior is meant the activity of the man or animal as it can be observed from the outside, either with or without attempting to determine the mental states by inference from these acts.

The various definitions can be illustrated concretely in the memory process. As *theory of mind*, psychology regards memory as one of the manifestations of mind and either is concerned with understanding mind through this manifestation or is content to describe remembering as one of the mental capacities. In fact, earlier theories of memory were content to assert that ideas were stored in mind or that they were impressions made upon a waxen plate. In either case, no details could be given as to how they were stored or how they might be reinstated. Mind was both an active agent and a receptacle, the sole means of accounting for mental states. If mind is to be defined as the sum-total of mental states in accord with the more recent suggestions, it is practically synonymous with consciousness, — the first definition merges into the second. As *science of consciousness*, psychology is concerned with a description of the different memory images, with the determination of the order of their appearance and with all else that is related to their structure and function. It takes into consideration nothing that is not to be discovered by the individual who remembers. It excludes consideration of mind as a storehouse, for that is not open to observation; and also of mind

as a wax plate or other similar entity. All that it can do is to determine the laws of succession of the mental states, and to describe the mental states themselves. As *science of behavior*, psychology only need investigate the capacity of the individual to remember. The individual is asked to repeat words or syllables a certain number of times under different conditions. After a certain period or certain periods he is tested to see how many he remembers. From these results laws can be formulated for the most effective means of learning.

The second and third of these definitions are alike in that neither implies any theories concerning what cannot be seen, what is not open to observation. Each would content itself with observation, from within or from without, of what actually takes place. As in all sciences, each form of observation may be subjected to experiment, the conditions of learning may be varied at will, the corresponding changes in results noted and formulated in laws. The choice between them must be made in terms of the methods that each emphasizes, and on the basis of the accuracy with which each can be made to cover the facts that are to be included under psychology. In strict definition, all is at once consciousness and behavior for most individuals. Few would deny that all behavior, to be known, must become conscious, either to the actor or observer; and none would deny that consciousness, unless it is to remain forever individual, must express itself in behavior. The choice of the definition 'science of behavior' turns, first, upon the fact that consciousness tends to imply something removed from observation, something mystical, a thing, rather than a series of phenomena; secondly, upon the fact that behavior is the more inclusive term; and finally, upon the doubt expressed by recent writers as to whether consciousness

exists, at least exists for them individually. It emphasizes the fact that laws of action must first be discovered, and that theories and theoretical explanations must be derived from the actual results of experiment and observation, rather than be accepted in advance.

**Behaviorism.** — The most recent development in method and theory has grown naturally from the great progress that has been made in animal psychology. Experiments on animals are of necessity limited to an observation of what the animal does under rigidly determined conditions. (Some of the earlier psychologists made inferences from the observed movements as to what mental processes might accompany them, but the results were so unsatisfactory that all assumptions about the consciousness of animals were abandoned.) The success in applying the method of purely objective experimentation to animals emphasized the possibility of applying the same method to man. If one could develop the laws of man's action by a study of his responses under different conditions, it would not be necessary to accept the unconfirmed statements of the observer, and would make it possible to check each observation by several individuals or to record them graphically. So far as it can be applied, the method offers obvious advantages and should be pushed to the fullest extent. Whether this can be the only method in psychology is still a matter of debate. Certain of the questions which interest the psychologist concern mental states, and these have been answered by the older methods. Up to the present time no objective investigations of these problems have been made, and we must either omit them or state the results of the older methods on the older presuppositions. Watson, the extreme behaviorist, relieves himself of the difficulty by omitting all mention of mental states, and by asserting

that if they do exist they cannot be made the basis of a science. Many of his more moderate followers are content with emphasizing the desirability of the objective method where available. Consciousness seems to them a fact of immediate experience. If it exists it should be taken into account in a study of behavior, when it contributes relative data. All psychologists, of whatever school, will hail with delight the fullest application of the objective methods; the behaviorists that it may supplant, others that it may supplement, introspection.

The three definitions do not differ essentially as to what the phenomena of consciousness are, nor as to the general laws that express them, but rather in the theoretical explanations which each offers. Thus the exponent of the extreme behaviorist view differs from the extreme subjectivist not in the facts he accepts but in that he does not believe that consciousness exists, or if it exists, that it plays any important part in controlling action. For the subjectivist, on the other hand, consciousness seems the final term by which all else must be explained; behavior is secondary. In the first definition, the use of mind is very obviously the introduction of a theoretical explanation. No one claims that it is ever open to direct observation, however important it may appear to the individuals who believe in it. These differences of opinion on theoretical points may very well be neglected in the development of a description of the mental life. After facts have been collected and laws formulated, the fundamental problems may be attacked in the light of those results. Laws are bound to suggest wider generalizations, and these in turn reveal fundamental causes or conditions.

**Psychology Treats Only Certain Phases of Behavior.** — Obviously, if we are to define psychology as the science of

behavior, we must limit its application, since all of the biological and even the chemical and physical sciences are needed to explain behavior in its completeness. In practice, we limit ourselves to the explanation of intelligent behavior. Roughly, behavior may be regarded as intelligent when it is modified by the earlier experience of the organism. All the acts of certain of the lowest organisms and some of the acts of the highest are to be explained altogether in terms of the physical stimuli and of the constitution of the organism. In consequence, these responses are relatively invariable, — the organism makes the same movements under the same conditions; such responses do not concern psychology. When behavior is modified, not merely by the physical stimuli and chance chemical conditions of the organism, but also by the results of earlier behavior, we have the first beginnings of intelligence, and the organism offers material for psychology. Even in the highest organisms, psychology is concerned only with the phases of behavior which cannot be referred directly to chemical and physical changes within and without the organism. It deals in general with the acts of the organism as a whole, rather than of the parts, and it considers the acts of the organism only in so far as they are not explained by physiology and other distinctly biological sciences. In general, again, psychology treats behavior in so far as it is determined by previous acts of the individual, by other more remote influences, while the other sciences treat the same behavior in so far as it is due to the activities of particular organs and to the more mechanical forces.

## The Scope of Psychology

**Psychology in its Relation to Other Sciences.** — If part of all behavior is to be explained by other sciences, by

physiology, by anatomy, and the other biological sciences, the psychologist must take the results of these sciences into consideration. He must know what part of the problem they solve and what they leave over for him to discuss. He must also use many of their results in attaining his own conclusions. Knowledge of the structure and function of the nervous system is particularly important, as in the higher organisms practically all behavior is an expression of nervous action. Capacity for the more complex forms of behavior develops with the nervous system, and defects in the nervous system are closely correlated with deviations from normal behavior. Consciousness, too, is closely related to the nervous system. One can become aware of external objects only as stimuli are carried to the brain by the sensory nerves; memory defects accompany injuries to definite portions of the brain tissue. In fact, we have every reason to believe that all forms of consciousness have definite accompaniments in the nervous system. Viewed from any standpoint, the problems of psychology are closely bound up with the problems of the nervous system. A knowledge of nervous anatomy and physiology is essential to an understanding of either consciousness or behavior. We shall begin our work with a brief survey of the more important facts of neurology. This survey, it may be well to state, is not part of the field of psychology. It is given here only because one cannot presuppose that all readers have a knowledge of the nervous system, and acquaintance with the facts is necessary to an understanding of many definitely psychological problems. A full preparation for commencing the study of psychology makes requisite also the results of physics and chemistry. All of the activities of the organism involve chemical processes, and the stimuli to action are physical. In brief, all of the sciences dealing

with any of the forces that arouse or modify action and with the nature of the organism itself must be of assistance to psychology.

In addition to the sciences to which psychology must look for aid in solving its problems, it also has close relations with many of the social sciences, which either depend upon it or share with it in the solution of their own problems. Sociology in its attempt to understand society must take into consideration the individuals of which it is composed, and welcomes whatever light psychology can shed on the subject. In many of its phases sociology is *social psychology*. Similarly, much of the work in economics depends upon a knowledge of mental laws. The economist, however, has for the most part developed his laws of human nature for himself from a study of practical relationships, rather than from the findings of psychology. The relationship of psychology to philosophy is, for the theoretical problems, closest of all. Psychology was the latest of the sciences to separate from philosophy, and the attitude toward many of the fundamental problems is still profoundly influenced by philosophical considerations. Each of the definitions of psychology discussed has developed in response to philosophical theories. On the other hand, many of the philosophical discussions presuppose a knowledge of psychology. There has always been an interaction between the two disciplines.

## Subdivisions of Psychology

**The Varieties of Psychology.** — The more usual classifications of psychology have been based upon the ways of approaching the subject, upon the methods used in the investigation, or upon the field that is treated. The older psychologies were divided into *rational* or *deductive*, and

*empirical* or *inductive* (on the basis of the fundamental method employed). Recently all psychology has tended to become empirical or inductive, particularly with the increased use of experiment; and the method of deduction has been applied only to topics that do not lend themselves to experiment or observation. Rational psychology as a separate field has largely disappeared. Even Wolff, who may be said to have introduced and certainly to have made large use of the distinction, was not able to keep the two apart; but was continually turning from one to the other. Two branches have received names from the direction of approach: physiological psychology and psychophysics. The former treats of the mental processes in their relation to the nervous system and its action. It is implied in all forms of psychology at the present time and differs from the others for the most part only in the relative amount of space devoted to the physiological aspects. All psychologists at present presuppose a knowledge of the nervous system and its action, even if they do not discuss it explicitly. Much the same may be said of psychophysics. This lays greatest emphasis upon the part the physical stimuli play in mental processes, and the way in which mental states change with changes in physical stimuli. Both physiological psychology and psychophysics were titles of important works on psychology, the one by Wundt, the other by Fechner. Closely connected with physiological psychology is objective psychology, a name given to several recent books. This not merely places the emphasis upon the nervous system and its activity, but actually leaves consciousness out of consideration altogether. It, like behaviorism, studies behavior from the outside only.

**Different Fields of Psychology.** — Psychology may be divided with reference to subject matter. Most psychology

deals with the adult human individual, but recently many additional and special fields have been developed.

*Social Psychology.*— Society, or man in the mass, may be studied, as well as the individual. A society shows many characteristics different from and in addition to the qualities of the individual. A mob, for example, will do many things that few if any of the individuals who compose the mob would countenance in calm moments. These and other phases of group psychology have been studied, and a series of important laws developed. Race psychology deals with the broader mental differences between races and is a natural extension of social psychology but has been less fully developed.

*Genetic Psychology.* — A second group of divisions of psychology, genetic psychology, treats the less developed types, either with the object of throwing light upon more complex human behavior or for their own sake. The most fully developed of these is *animal psychology*. The question as to whether or not animals are intelligent and how their intelligence compares with man's has always interested students, but until within the last two decades most of the conclusions were based upon anecdotes or, at most, upon the chance observations of travellers and naturalists. These were obviously not trustworthy. More recently, experiments upon animals have been carried on by both biologists and psychologists, with very important results. The behavior of typical animals from the protozoa to the apes has been studied exhaustively. Much light has been thrown upon their own activities, and many points in human psychology have also been illuminated by these results. The development of the individual has also been investigated. *Child study* has offered a number of conclusions that make easier an understanding of the complicated activities of

man. The earliest years and the period of adolescence have received most attention.

*Abnormal Psychology.* — Still another important series of problems has arisen in connection with different forms of mental deterioration, the psychology of the abnormal, or pathological psychology. The relation of these studies to normal psychology has been twofold. They have greatly aided in an understanding of the normal individual. One is very much more certain that a voluntary act depends upon certain stimuli or sensations when it can be shown that the absence of that stimulus causes a defect in the movement. Disturbances of the self have given a more profound knowledge of what the self is or is not than centuries of speculation and introspection. Slighter defects of sensation, color blindness and partial deafness, not to mention the impairment of memory and related processes, have all given valuable aid in the unravelling of psychological problems, or have substantiated results obtained in other ways. On the other hand, psychological methods and psychological results have been adapted to the study of the abnormal and defective minds with much theoretical and practical benefit. Certain standardized tests have come into use which make it possible to determine within fairly close limits the degree of intelligence of the individual. These have proved of value in the schools in selecting the children who are unable to profit from the usual training, and make it possible to give them special instruction. It has been shown by an examination of criminals and paupers that, in a large number of cases, a mental defect is responsible for their failure to fit into society; and the necessity for special care that shall provide the ounce of prevention has been emphasized. Many of the methods used to-day for the diagnosis of insanity have also been developed in psychological labora-

tories, and much of the treatment has been an outgrowth of psychological principles, an application of psychological methods.

**Our Problem.** — In this work we shall restrict ourselves to a study of the normal adult human individual. Reference will be made to the other branches of psychology only in so far as their results aid us in understanding this central problem; they render valuable aid at practically every point. We shall use the results of all methods, but shall enter as little as possible into the controversies as to whether any one method is theoretically justifiable. We shall assume that there is a body of fact that is independent of the theoretical discussions. Thus, in connection with the difference of opinion as to whether observation or introspection is *the* method in psychology, we shall remain neutral, and make use of the contributions of each method. After all, the controversy concerns us only in its effect upon the form of expression that may be used to state the results rather than in the validity of the results themselves. Most of these results may be expressed equally well in terms of one theory or the other, and where they cannot we shall use the terminology best suited to the particular statements in hand. The facts are important and will persist, while the theories that interpret them are in constant flux. We shall be concerned primarily with facts, and the theories will be considered only where they serve to make clear the facts.

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# CHAPTER II

## THE NERVOUS SYSTEM

BROADLY speaking, the physical basis of mind is to be found in the nervous system. In a very general sense, the nervous system is the organ of mind. When, however, we approach it from the physical side, it is also the organ which makes possible the activities of the body, which permits external stimuli to act upon the muscles, and coördinates the different movements so that they may bring about harmonious and unified action. An understanding of the action and even of the structure of the nervous system is very much easier if we keep the emphasis upon the relation of the nervous system to bodily movement — treat it first for itself — than if we think of it in its relation to consciousness. The problem of the relation of body and mind may be taken up when we know more of body. The nervous system in vertebrates is made up of the brain and spinal cord with the sensory and motor nerves that extend from these central organs to the sense organs and muscles. The brain fills the upper part of the skull, while the spinal cord is found in the spinal column. The details of the structures can be understood more readily if we consider them later in connection with their development in the race and in the individual.

### BEHAVIOR OF LOWER ORGANISMS

**Life Processes in Cells.** — It is much easier to understand the action of higher animals and the nervous structures

themselves if we commence by describing briefly the animal organisms which do not possess nerve tissue, the so-called unicellular organisms. This is the type of organism from which all the higher forms are assumed to have developed. Of the single-celled animals, or protozoa, one that is most

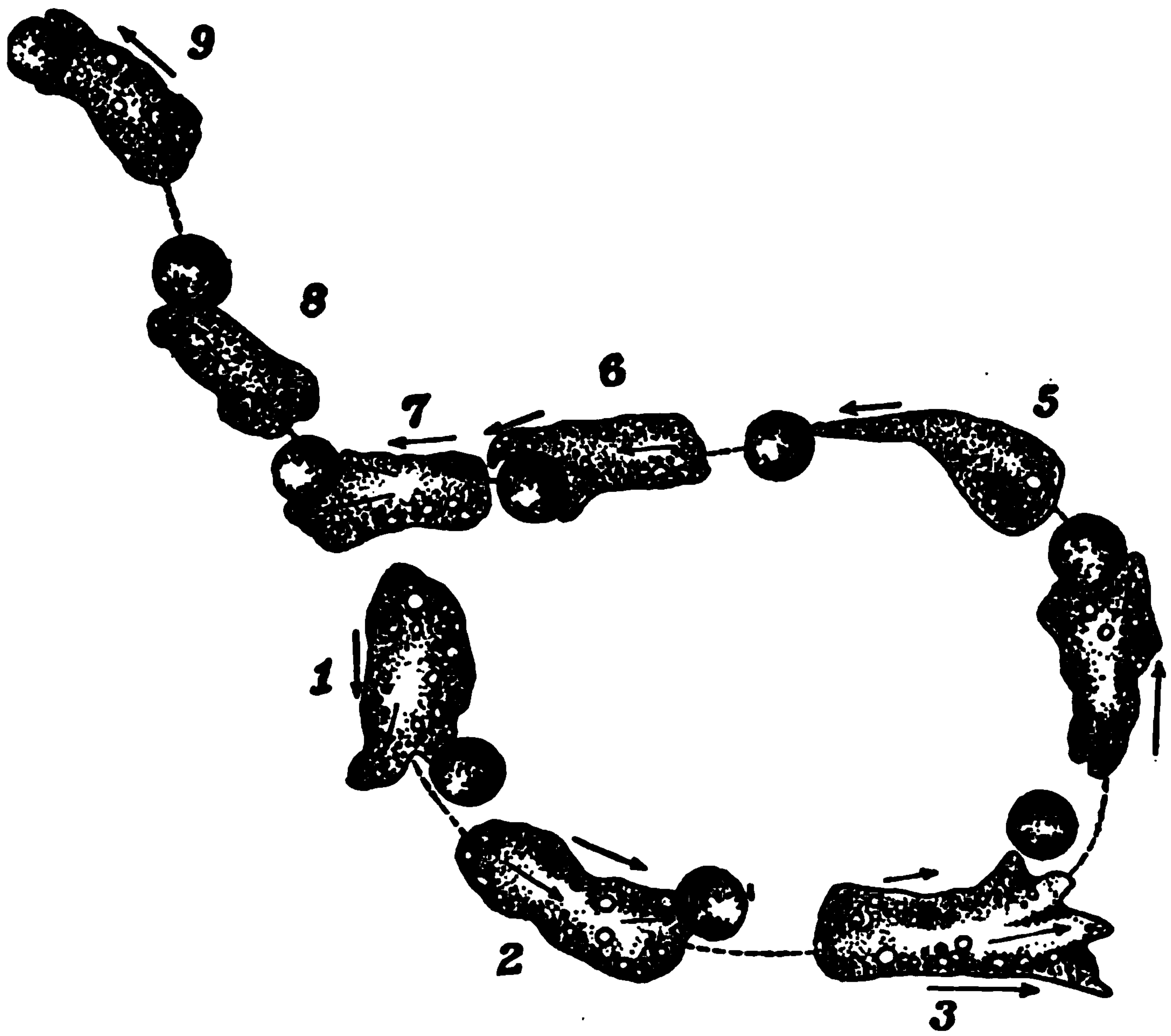



FIG. 1. — Amœba chasing and attempting to ingest a euglena. (From Jennings.)

frequently used to illustrate the type is the amœba. It is merely a drop of liquid of unknown but highly complex chemical composition contained in a delicate semipermeable membrane. Since this is the original tissue from which all other living matter is developed, it is known as protoplasm. We know that protoplasm is made up of highly unstable chemical compounds, mostly hydrocarbons, but the different components have never been completely isolated

or analyzed. Whatever the composition of this chemical substance, it is constantly undergoing change. It takes to itself other organic compounds and oxygen and gives off carbonic acid. It is constantly taking something from the medium in which it lives and giving off waste products. Both of these changes take place through the semipermeable membrane by a process which the physicist calls osmosis. Within the body of the cell is a darker spot, known as the nucleus. This nucleus is closely connected with the nutritive processes and the subdivision of the cell. Much still remains to be known of the life processes in the cell. We can only give the briefest account of what is known — that some chemical processes must go on within the cell, that the materials involved are admitted to the cell by osmosis through the membrane, and that these processes taken together make possible, if they do not constitute, what we call life.

**The Activities of Protozoa.** — If we study the activities of one of the unicellular organisms, we find that in a simple way it can do almost everything that the most highly organized animal can, and that it follows the same fundamental laws of behavior. It takes nourishment, it breathes, and, what is most important from our point of view, it moves upon stimulation of any part. If particles of a certain chemical composition come into contact with its membrane, it enfolds them, and the process of digestion through the membrane of the cell begins. If other particles of another kind come into contact with it, it moves quickly away. When in contact with a solid body, it may send out a prolongation of its body in the form of a foot or what is known as a pseudopod (false foot) which attaches itself to the surface, and the whole body then draws itself up to the foot, which is then withdrawn into the rest of the body.

The single cell is stomach, lung, and organ of locomotion, in one.

Study of the responses of the amoeba and of the stimuli to which it responds shows its similarity to the higher organisms. When stimulated gently by a solid surface, its activity is not changed, but, if the excitation is stronger, it at once stops all movement and rolls up into a ball. If the stimulation is continued, it may send out a pseudopod on the opposite side and roll away from the stimulus. In these two ways the protozoa respond to light, heat, the motion of the liquid medium, the attraction of gravitation, and to the presence of chemicals in the liquid. In general, beneficial stimuli have no effect, while harmful stimuli cause a movement that removes the organism from its neighborhood. Certain organisms, the Stentor that Jennings worked with, for example, modify their reactions in accordance with the result of earlier reactions, and thus give the first evidence of learning. If we use variability of response as a mark of intelligence, this may be regarded as an intelligent act. The first response of the Stentor when stimulated is to withdraw into its tube. After this has

FIG. 2. — Stentor stimulated by carmine particles. (From Jennings.)

been repeated several times, it changes its form of response to bending to one side to escape the contact. Later it may, when strongly and repeatedly stimulated, loosen its hold on the tube and swim away. These latter responses were called out by permitting water mixed with carmine particles to reach its disk.

Each of these responses is to be thought of as the result of the transfer of a chemical stimulus from the point of stimulation to a more or less remote portion of the cell where the movement is made. Did we know the exact nature of the processes in these simplest cells, many of the problems of man's action would be solved. So far we have only commenced in that direction, although advances are being made frequently. At the present stage of our knowledge we can do no more than express the belief that a chemical or physical explanation may some day be found. Meanwhile we may use the action of these simple organisms as a type of the action of cells in general.

## THE NERVE CELLS IN MAN

**Man a Colony of Cells.** — These responses are important for us from the fact that one may think of all of the higher organisms as compounded of cells like these simple unicellular organisms, which have undergone various modifications as a result of living together in a colony, but still retain many of the characteristics of the original free-swimming protozoa. For our present purposes, the body of man may be pictured as a mass of cells in which each class has developed specializations that fit it to fulfil some one function. With increased capacity for this function, others of the primitive capabilities have been lost. Nevertheless the rudiments of all the capacities of the complex organisms are to be found in the unicellular organisms. In the

body, the nerve cells are among the least modified. Unlike the bone cells, for example, that become so filled with salts as to retain but slight similarity to the original, the nerve cells lack motion alone of the capacities of the prototype. Only certain of the blood corpuscles retain more of the original properties; the leucocytes, or white blood corpus-

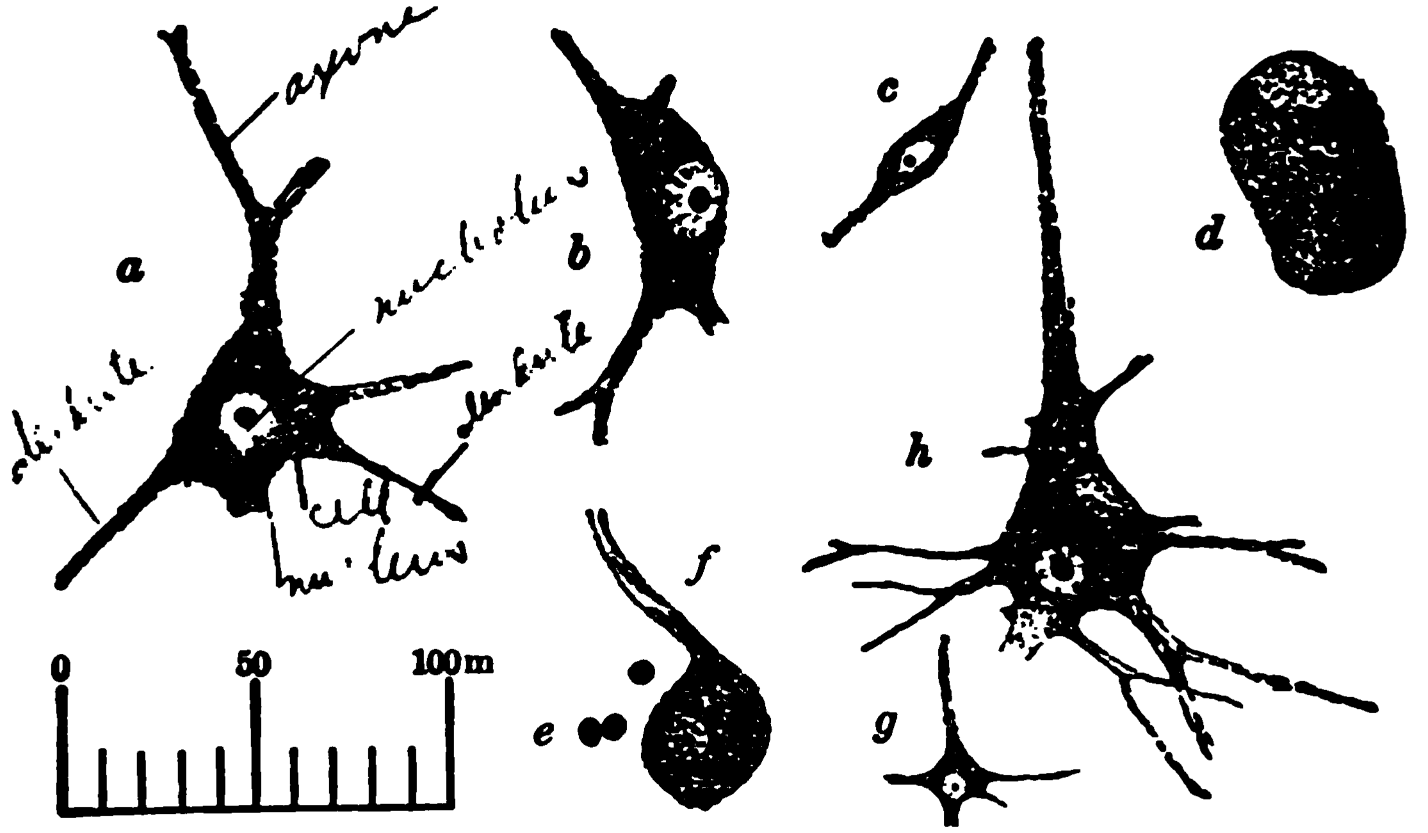



Fig. 3. — A group of human nerve-cells drawn to the same scale. *a*, small cell from the ventral horn of the cord; *b*, cell from Clarke's column; *c*, small nerve-cell from tip of dorsal horn, thoracic cord; *d*, spinal ganglion cell, cervical root; *e*, three granules from cerebellum; *f*, Purkinje cell from cerebellum; *g*, small pyramidal cell from second layer of central gyri of cortex; *h*, giant pyramidal cell from same region. (From Donaldson, after Adolf Meyer.)

cles, seem to live almost as independent an existence in the blood as the amœba in its watery medium.

**Morphology of Neurones.** — The cells of the nervous system have retained especially the sensitivity and conductivity of the unicellular forms. In brief, the elements of the nervous system, known as neurones (also spelled neurons), consist of a central cell, the representative of the cell body, and numerous processes that extend in all directions from that cell body. The cell body is of a more or less irregular shape and varies in diameter from about

$\frac{1}{300}$ to $\frac{1}{10}$ of a millimetre. The shapes can be seen from the accompanying diagrams. Within the body of the cell are found a nucleus and a nucleolus, as in all cells. Within the

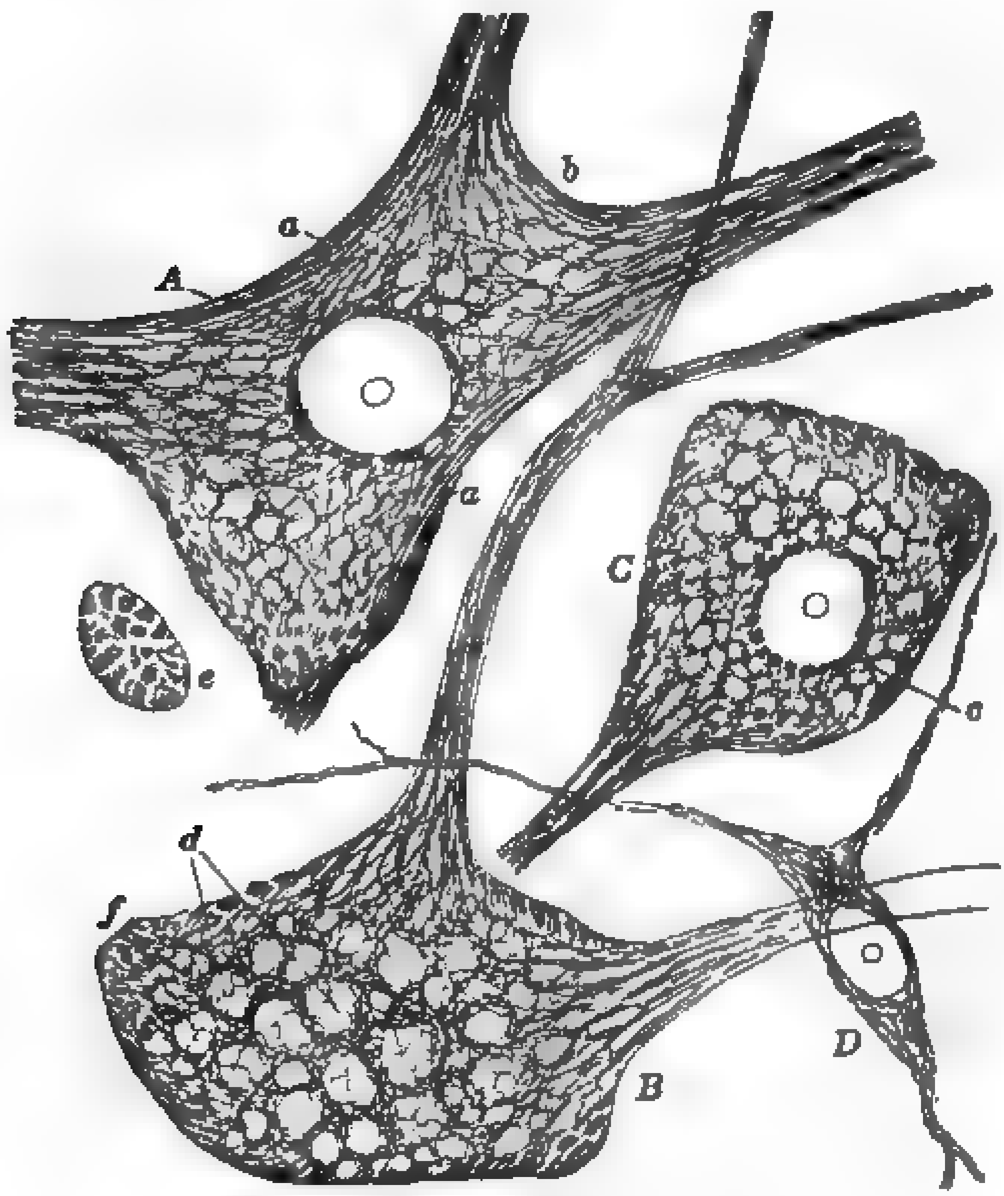



FIG. 4. — Cells from the cord of a rabbit, showing internal structures. *A*, *B*, *C*, motor cells; *D*, small cell from the spinal root; *a*, bundles of neurofibrils; *c*, perinuclear plexus; *d*, the empty areas correspond to the Nissl bodies; *e*, section of a dendrite, showing similarity to cell tissue. (From Cajal.)

protoplasm are small particles that stain easily, named Nissl or tigroid bodies, the former after their discoverer. In many cells can also be seen fine fibrils that run through the bodies of the cells and into the processes. It is not pos-

sible, however, to assert positively what function these different parts of the cell have. The nucleus and Nissl bodies are probably closely connected with the nutrition of the cell. Some theories assign a highly important function to the fibrils, but the balance of opinion seems opposed to regarding any one part of the cell as the fundamental seat of its activity. We cannot as yet analyze the action of the cell into elements, but must think of it as acting as a unit.

**Axones and Dendrites.** — The processes or extensions of the neurones are of two sorts, distinguished rather by function than by structure. One, which serves to conduct impressions away from the cell body, is usually long, with relatively few branches, and these at right angles to the main stem. It is called the axone (also spelled axon). The axone terminates in the end brush, a number of short branches, each of which is probably continuous with a fibril in the axone. The other is usually made up of a number of fibres much shorter and much branched, is in fact usually a thick network like the roots of a tree, an appearance that gives the whole its name, the dendrite. This usually carries impressions to the cell body. The axones may be of considerable length. A single axone extends from the brain to the lower cord in the case of the motor fibres and sensory axones from the cord to the medulla. The axones carry impulses away from the cells. The dendrites are nearly always relatively short, less than a millimetre in length. The one striking exception is found in the case of the dendrites of the sensory neurones whose cells are found

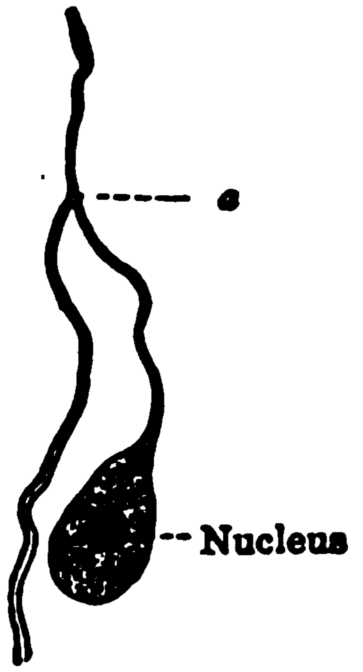



FIG. 5. — 'T'-shaped cell from spinal ganglion of frog. (From Boehm-Davidoff-Huber's "Histology.")

in the spinal ganglia, masses of nerve tissue near the cord. They serve to transfer impressions from the organs of the skin and lower body to the cord and brain. The process that runs to the skin may be two feet or more in length, extending from the skin of the toe, for example, to the T-shaped cell body in a spinal ganglion in the lower part of the back. In appearance it is not to be distinguished from the fibre of an axone, but its function is to carry an impulse to the cell, the function of a dendrite. It is sometimes called a teledendrion, or long dendrite, to avoid the difficulty of classing it either with the axone or with the dendrite.

**The Sheaths of the Axones.** — The axones do not show a homogeneous cross section, but consist of several parts. In the centre is a core of protoplasm continuous with the structure of the cell body. In it may be traced the minute fibrils that were mentioned above as found in the cell. About this central core of nervous tissue are found one or two coverings or sheaths. One, the outer, known as the neurilemma, or sheath of Schwann, is a thin white layer, segmented or notched at intervals. Many fibres have within this outer sheath a thicker coating of fatty substance known as the medullary or myelin sheath. This is absent in the nerves of the sympathetic system and at the early stages of the development of the fibres in the brain. The neurilemma is found on the peripheral nerves, but is lacking within the central nervous system. The axone lacks both sheaths, too, for a short distance after it leaves the cell body and the end brush is also always bare. Flechsig has inferred that the medullary sheath is necessary for the action of brain fibres from the fact that this sheath develops successively on different groups of fibres, as the individual grows older before and after birth, and that fibres

continue to be medullated up to and beyond middle age. The facts that some fibres are always without this sheath and that animals can learn before their cerebral fibres are medullated make its importance somewhat doubtful. The central core, then, may be regarded as the path of the impulse, and the sheaths as largely protective. In a peripheral nerve several thousands of these fibres may be united. In the optic nerve it is estimated that there are 100,000 of them grouped together. Between the nerve

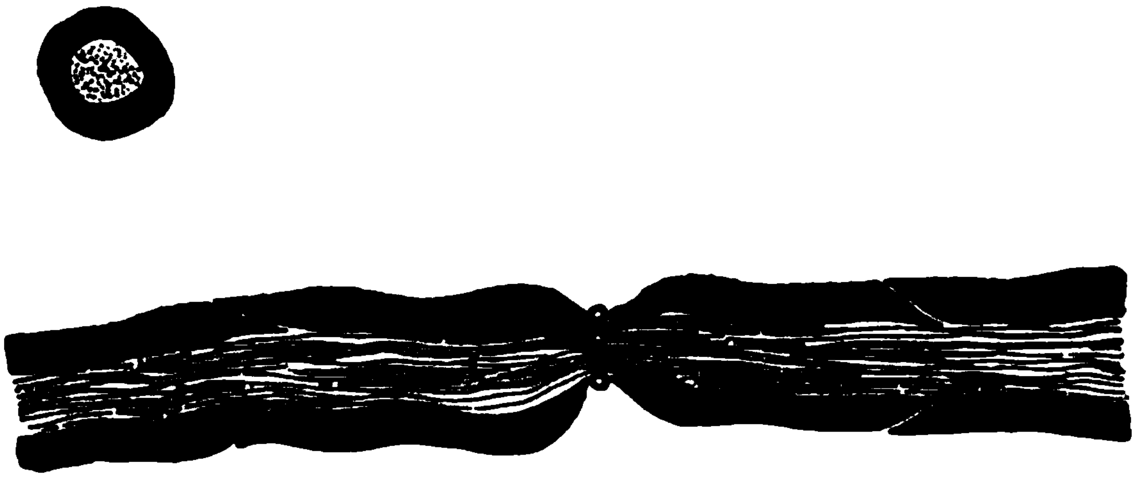


FIG. 6. — Longitudinal and transverse sections of a medullated nerve fibre. The myelin sheath is shown in black; the central protoplasm shows its fibrous structure. (From Barker, after Biedermann.)

cells are numerous cells of a different character, the neuroglia cells. They are supposed to have no part in the conductivity of the nervous system, but to constitute supporting structures. Their exact function is not known. Their shapes may be seen in Figure 7.

## THE GENERAL PLAN OF THE NERVOUS SYSTEM

**The General Outlines of the Nervous System.** — The nervous system of man is altogether made up of these neurones held together by their own cohesion and the pressure of the bones and other surrounding tissues. The peculiarities of appearance of the different structures are due to the way in which the different elements are combined to

constitute the masses. As one looks at the nervous system of a mammal, one may distinguish three parts. The largest is the *cerebrum*, which fills the upper portion of the skull, next below is the *brain stem*, so called because it may be regarded as supporting the brain proper. The largest part of this is the *cerebellum*, which lies in man just below the cerebrum, although it is attached to the brain stem below several of the other important structures. In the brain stem between the base of the cerebrum and the point of attachment of the cerebellum are the *corpora quadrigemina* and the *thalami*. The latter are at the base of the cerebrum, the former just below it. The lowest and smallest portion of the brain stem is the *medulla*. Just below that is the *spinal cord*, the third of our main divisions, which extends about two-thirds the length of the spinal column. The position of these more prominent organs should be carefully studied in Figure 8. Superficially regarded, the most striking differences between different structures are in the colors. The cortex, or outer layer of both cerebrum and cerebellum, is gray; the cord is white. The gray color is given by masses of cell bodies closely crowded together, while the white color is given by the white sheaths of the nerve fibres. Similarly, a section through any part of the central nervous system will show masses of white matter and other masses of gray matter. In the cord the centre is gray, the outer parts white; in the cerebrum the relation is reversed, but in each case the

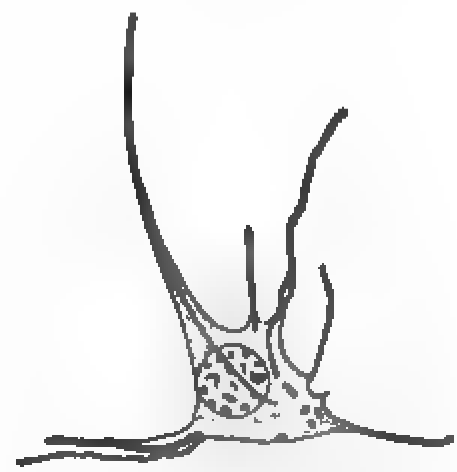


FIG. 7. — Neuroglia cell. In this preparation the cell is prominent. In the more usual method of staining, the fibres are more striking and give the so-called spider cells. (From Huber, after Joseph.)

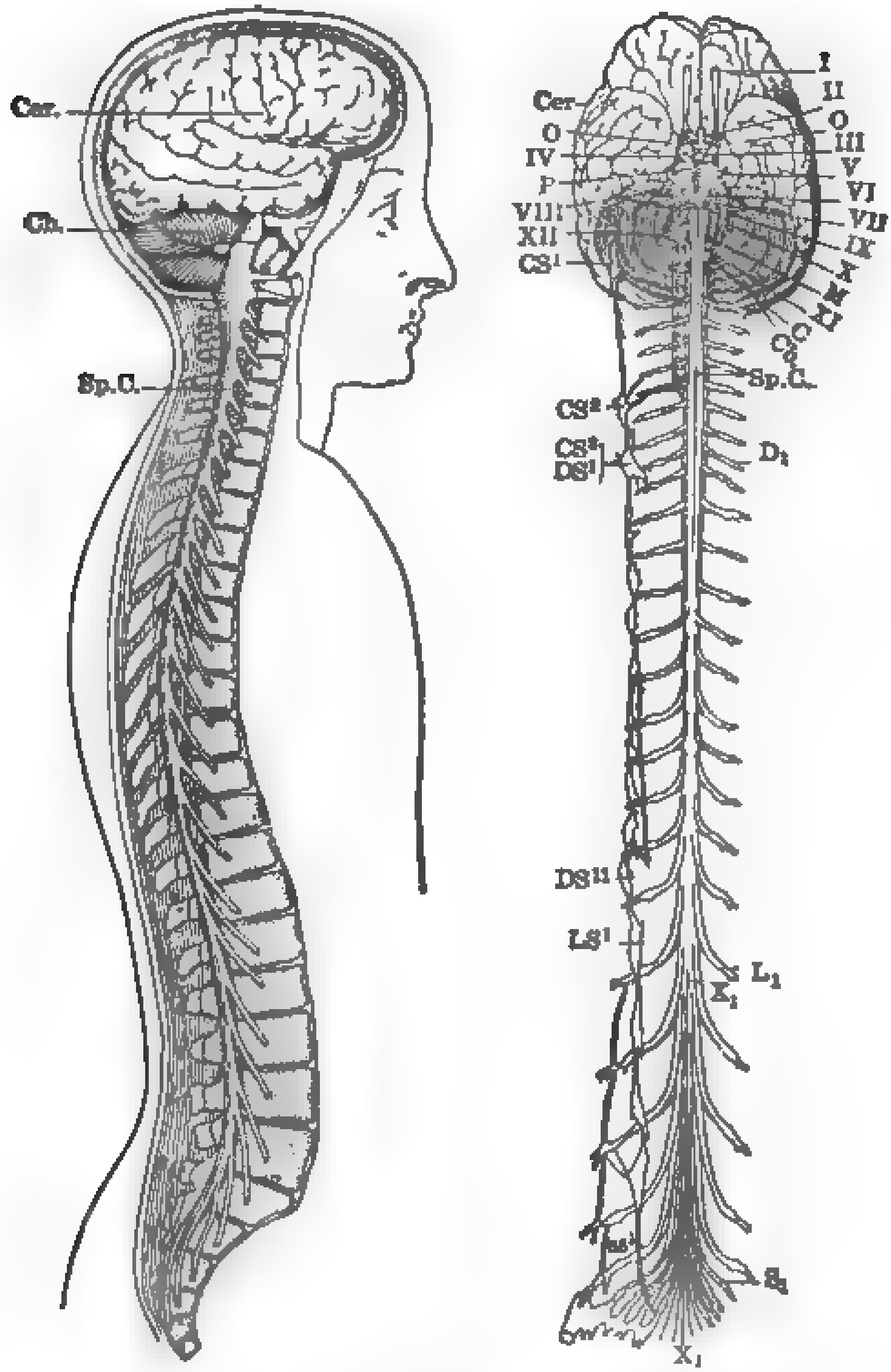



FIG. 8. — The nervous system as a whole. On the left it is seen from the side in position in the body; on the right exposed and seen from the front. *Cer.*, the cerebrum, *Cb.*, the cerebellum, *Sp.C.*, the spinal cord; *P*, the pons; *M*, the medulla. The other letters designate nerve trunks going to the central nervous system and connections with the sympathetic system. (After Bougery.)

gray matter is a mass of cells, the white a mass of axones. Separate masses of cells are known as ganglia.

The structures of the nervous system may also be grouped with reference to function. From this standpoint cells and fibres may be divided into sensory or afferent, associative or commissural, and motor or efferent. The sensory neurones are connected with sense organs, directly or indirectly. The axones conduct from the periphery to the centre. The first cells of sensory ganglia are outside of the central nervous system, either in the sense organ, or in ganglia near the central nervous system, and their axones connect with other cells nearer the brain. The commissural cells and fibres transfer the impression from sensory cells to motor cells. The motor or efferent neurones stand in immediate connection with the muscles, or with neurones which serve to innervate the muscles, — are members of the chain that conducts impulses from the centres outward. The neurones that possess these different functions cannot be distinguished structurally. The functions depend rather upon the connections in which the neurones are found than upon their structures.

**Development of Embryo.** — To understand the structural relations, one must go back to the development of the nervous system as a whole. Many relations, very complicated in the developed organism, are very simple in the earlier stages. The complexities are caused by the conditions of growth. Our sketch of the development must be very brief, with many omissions, but even this may be helpful at some points. The complete adult is developed from an original cell, the fertilized ovum, by a process of division. The original cell divides into two, each of these into two, and so on. At first the derived cells are exactly like the original so far as can be made out. They are

grouped compactly. The first sign of differentiation comes when a hollow appears within the mass, and the enclosing cells divide into two layers, an outer, the ectoderm, and an inner, the entoderm. Soon a third intermediate layer develops from the others to constitute the mesoderm.

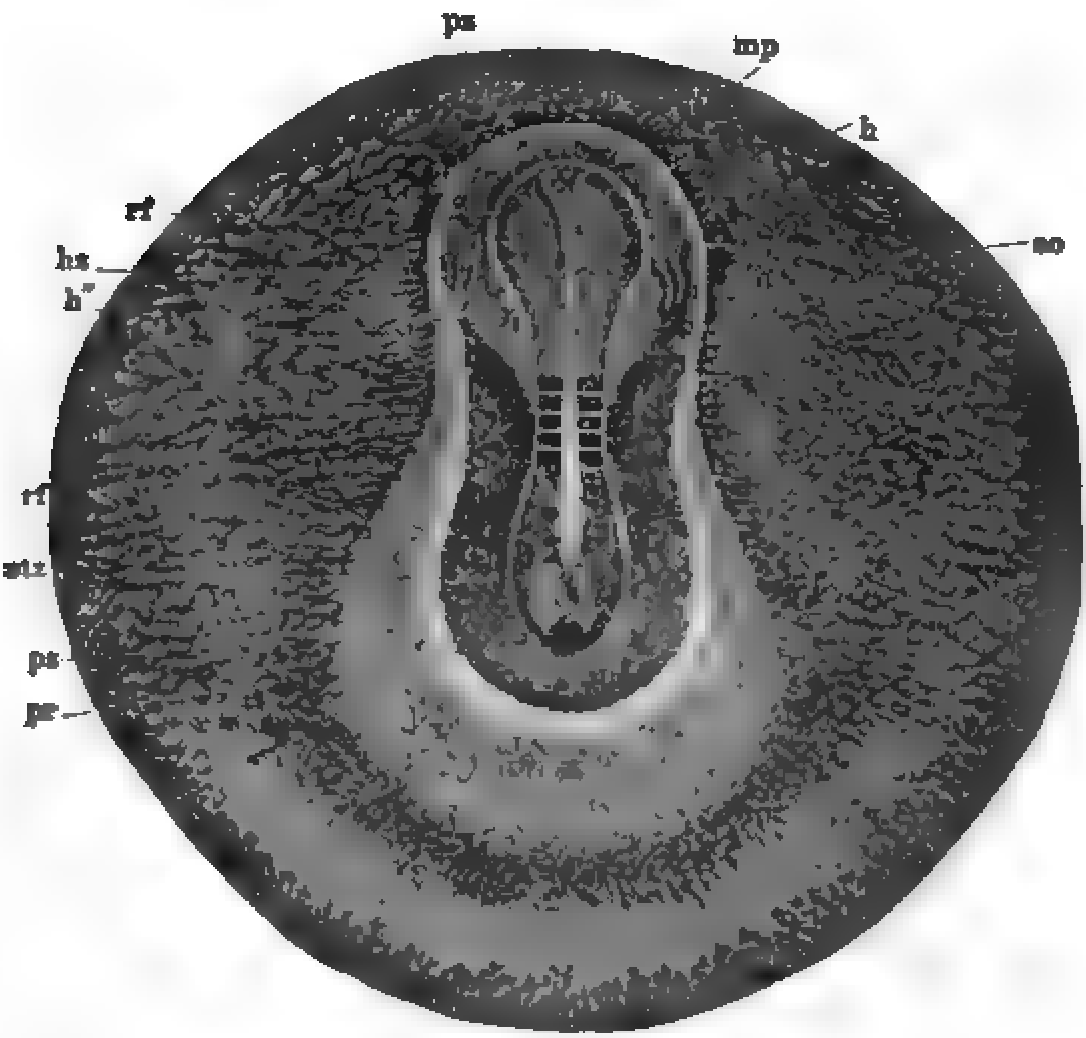



Fig. 9.—Embryo of a rabbit at eight days to show the neural groove. *rf* is the neural groove; *h*, the region in which the fore-brain is to develop. (From Kölliker.)

These layers may be distinguished throughout the remaining development and give rise to different parts of the organism. The entoderm gives rise to the inner wall of the internal organs, and to certain organs, as the liver and pancreas. From the mesoderm develop the supporting structures, connective tissue, bone, muscle, and the body of most of

the internal organs. The ectoderm develops into the skin and its appendages, the mucous membrane of the mouth and nose, and, what concerns us most, into the nervous system and the nervous parts of the sense organs.

**The Development of the Nervous System.** — It is interesting to note how the outer layer of the embryo gives rise

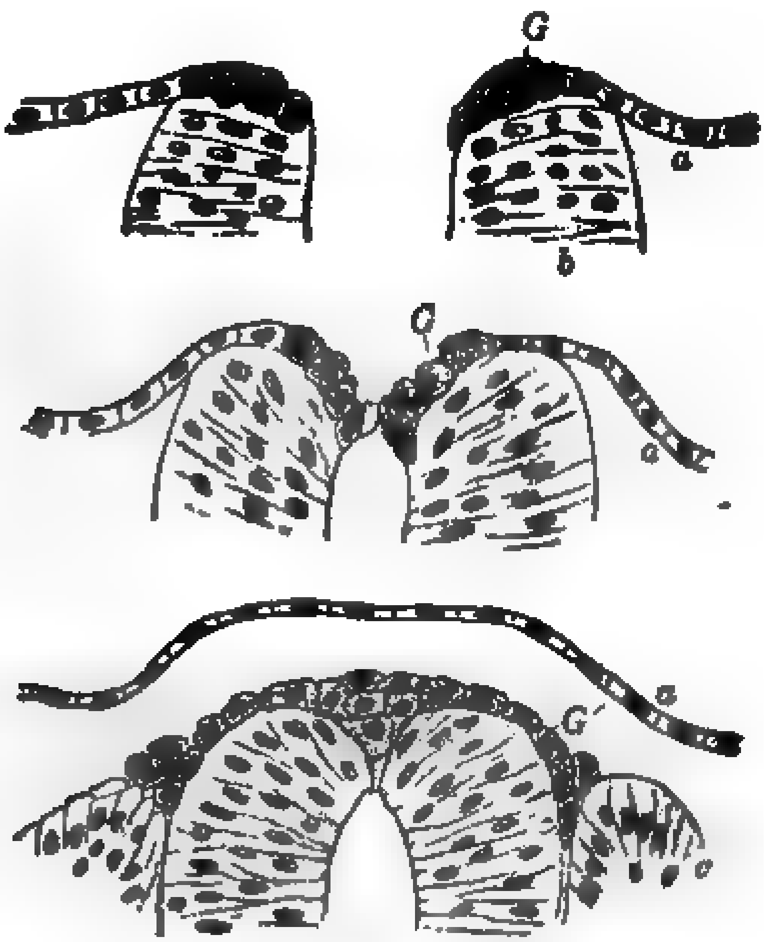



FIG. 10.—Closing of the neural groove. The figure at the top shows the groove still open; in the next, the sides approximate each other; in the lowest, the closure is complete. *G*, the cells from which the spinal ganglia develop, *a*, the ectoderm; *b*, the epithelial lining of the medullary tube.

to the nervous system which finally becomes embedded so deeply in the structure of the body. Very early in the embryonic life, within the first two weeks, there appears upon the surface of the embryo a slight depression known as the neural groove (Fig. 9). This gradually grows deeper, and finally the upper edges grow together and form the

neural tube (Fig. 10). From the walls of this tube the entire nervous system grows. The forward end becomes the brain, the other longer portion, the spinal cord. The cells that line the tube give off first masses of cells with radiating fibres that serve as a supporting structure or scaffold

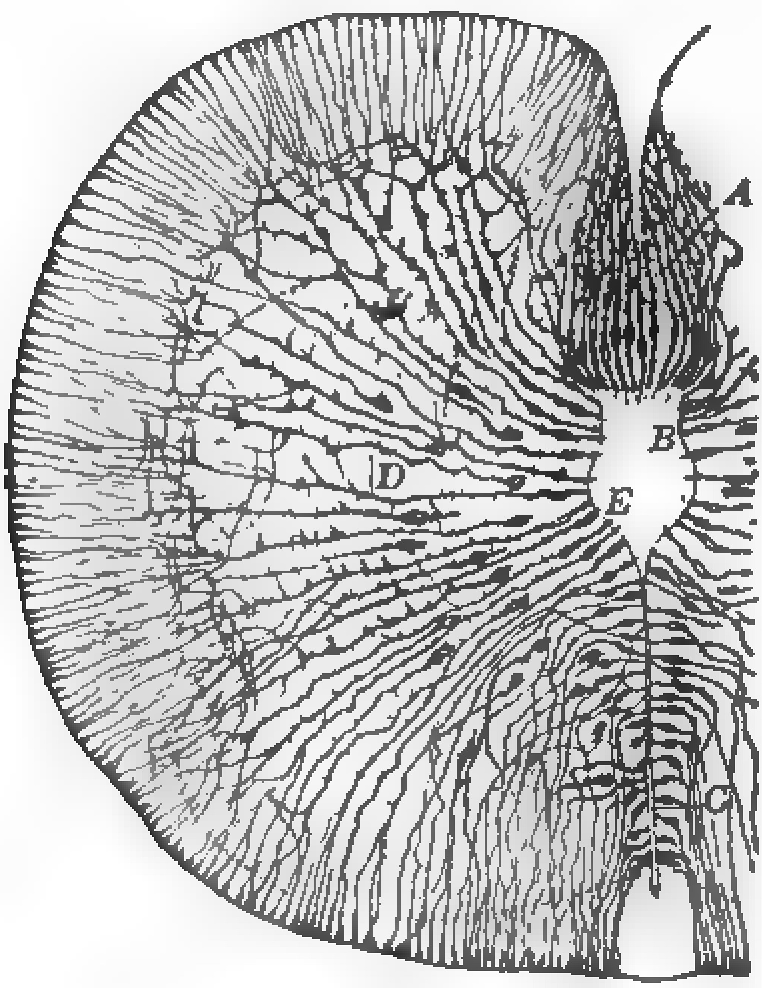



FIG. 11. — The ependymal or supporting structure of the embryo cord. (From Cajal.)

(Fig. 11). Some at least of these develop later into neuroglia cells, the supporting tissue of the central nervous system. This first supporting structure takes the general form of and may be said to prepare the way for the truly nervous structure. After the supporting or ependymal structure is well developed, later divisions of the cells lining the tube give rise to embryo neurones or neuroblasts. These make

their way outward toward the position they are to occupy in the adult cord. As the neuroblasts develop they send out processes, axones and dendrites. The axones grow outward to the structures they are to supply. A section of the cord at the end of the first month shows a layer of epithelial cells about the central tube, farther out the neuroblasts and then the axones (Fig. 13). Everywhere in the brain as well as here in the cord the principle holds that the processes are outgrowths of the cell bodies.

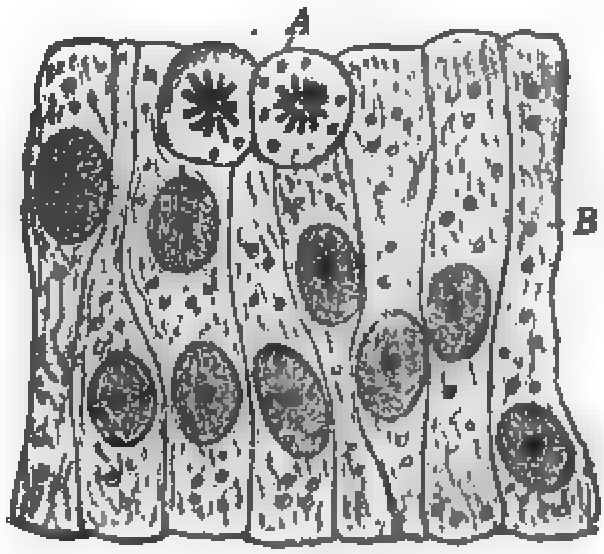



Fig. 12. — Epithelial cells lining the neural tube and germinal cells, *A*, that have developed from them. (From Cajal, after His.)

The axones grow out from the cells up the cord to the higher centres, and on the ventral side in particular outward to the muscles, even to the remote parts of the body. Meanwhile the sensory neurones are developing in the dorsal ganglia. When the walls of the neural groove grow together to form the tube, portions of the ectoderm are cut off both from the tube and from the

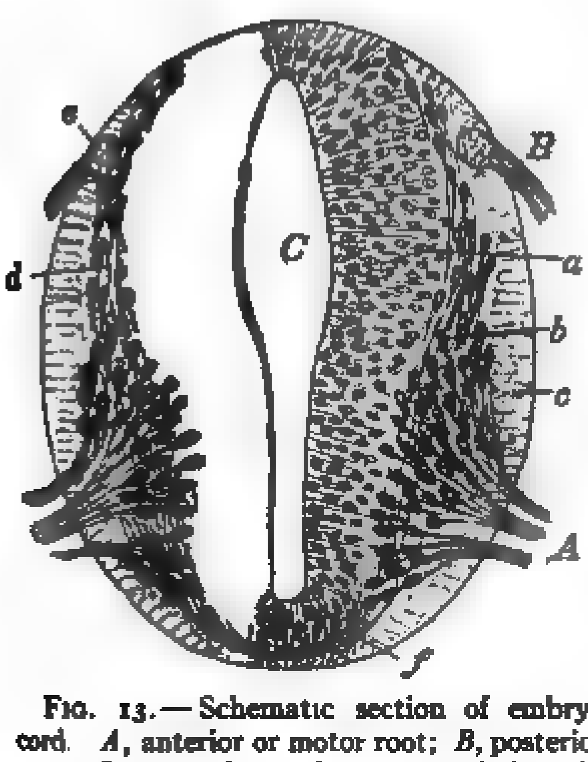



Fig. 13. — Schematic section of embryo cord. *A*, anterior or motor root; *B*, posterior root; *C*, central canal; *a*, epithelial wall; *b*, neuroblasts or embryo neurons, *c*, the primordial white matter. (Cajal, after His.)

surface. They move away from the median plane, and are surrounded by mesoderm tissue. The original ectoderm cells give rise to neurones. At first the processes of the


Fig. 14. — Development of dorsal root ganglion with cord. *A*, motor nerve; *B*, posterior root, fibres from ganglion entering cord; *E*, 'T'-shaped cells of dorsal ganglion in their bipolar stage; *e*, sensory nerve, dendrites of 'T'-shaped cells. (From Cajal.)

neurones grow out from either end; one goes outward to the end organ in skin and muscle, the other grows into the cord and sends fibres upward in the back part of the cord or into the central gray. Later in the development, the two processes grow together for a short distance from the cell

and then grow off at right angles to the original stem. They thus resemble a 'T,' and the cells are known as the 'T'-shaped cells. Before birth the germinal layer stops giving rise to new cells and forms a single layer of cells lining the central tube.

**The Development of the Anterior Portion of the Neural Tube.** — The growth of the forward end of the neural tube,

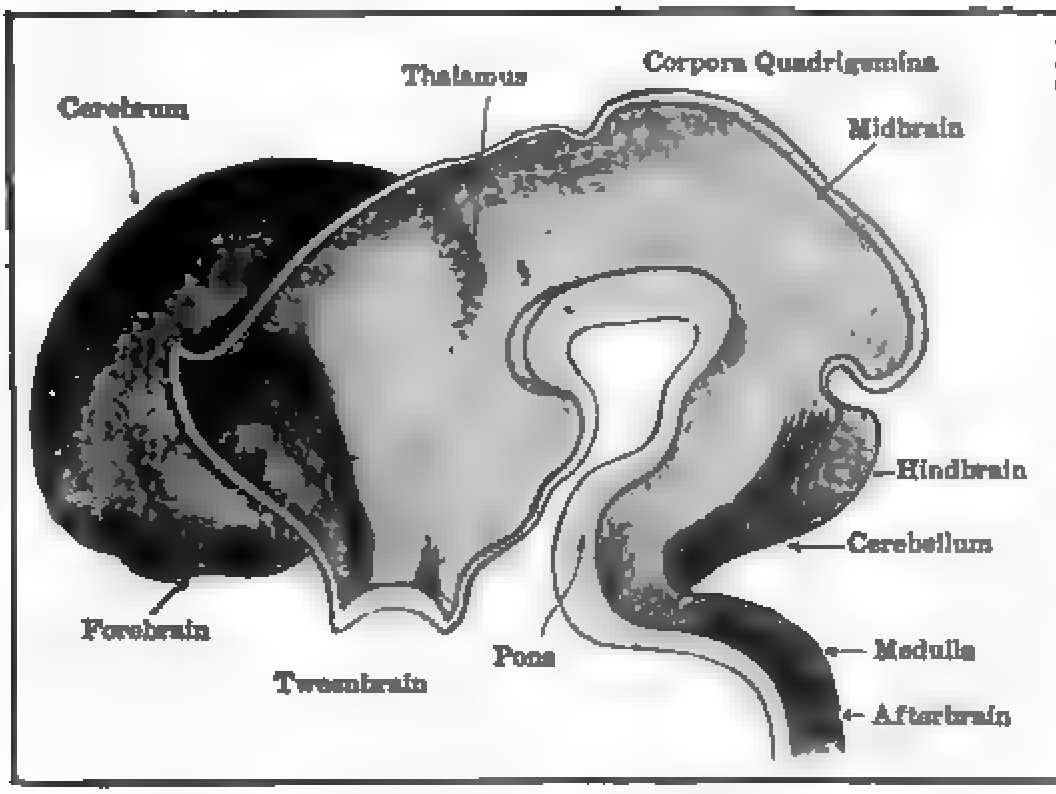



Fig. 15 — The five-vesicle stage of the human brain, giving names of vesicles: fore-brain, tween-brain, etc., and the parts of the adult brain that develop from each. (After His.)

the part from which the brain develops, follows much the same plan. The supporting structure and the neuroblasts appear as in the cord. One difference should be emphasized, however, that the neuroblasts are projected farther from the tube and the axones grow inward and extend up or down within the masses of cells. In consequence the white matter is, for the most part, within; the gray, on the surface. One other problem upon which development throws considerable

light is in the longitudinal arrangement of the parts. By the end of the second week, the forward end of the tube bends sharply downward, ventrally, and becomes divided into separate pouches or vesicles. At first three, later five, vesicles are to be seen. These are marked by constrictions in the tube at four places. Two most marked are just before and just behind the bend in the tube. The vesicle between is the mid-brain. The region in front is divided by a shallower groove into end-brain or fore-brain, and tween-brain, while the portion just behind is similarly divided into the hind-brain and after-brain.

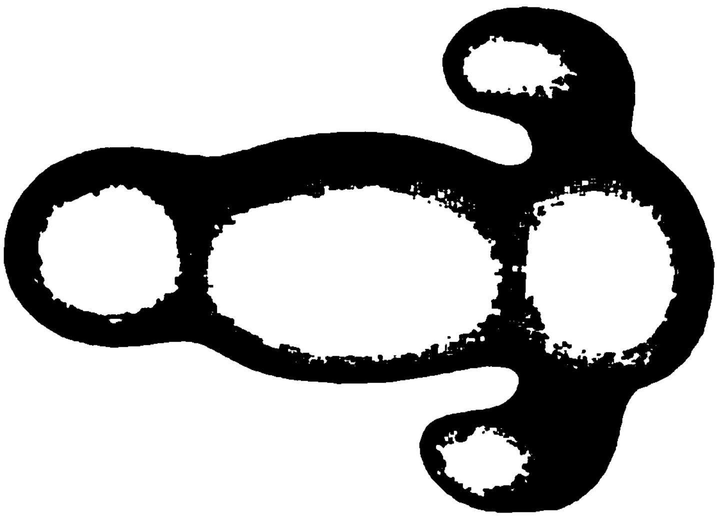


FIG. 16. — Development of brain vesicles seen from above. The hemispheres may be seen growing from sides of fore-brain. (From His.)

These early divisions give the name to the corresponding parts of the adult nervous system. The cerebrum develops from the fore-brain, the thalamus, and other parts from the tween-brain, the corpora quadrigemina and other structures from the mid-brain, the cerebellum and pons from the hind-brain, and the medulla from the after-brain. In each the walls are very much thickened and at many points there are very large outgrowths, but all grow from the lining of the original tube by the process of cell division indicated above. The original cavity undergoes changes of shape in many places. It becomes much heightened in the hind-brain to constitute the fourth ventricle, in the mid-brain it retains its original shape, and continues small as the aqueduct of Sylvius. It broadens in the tween-brain to the third ventricle and bifurcates in the cerebral hemispheres to form the lateral or first and

second ventricles. Nevertheless it remains continuous throughout from the lateral ventricles in front to the bottom of the spinal cord. It is filled everywhere with the cerebro-spinal fluid.

**The Cerebrum.** — The development of the cerebral hemispheres deserves special mention. They appear early as lateral swellings on the fore-brain. These grow first to the side, then upward and back until they cover mid-brain

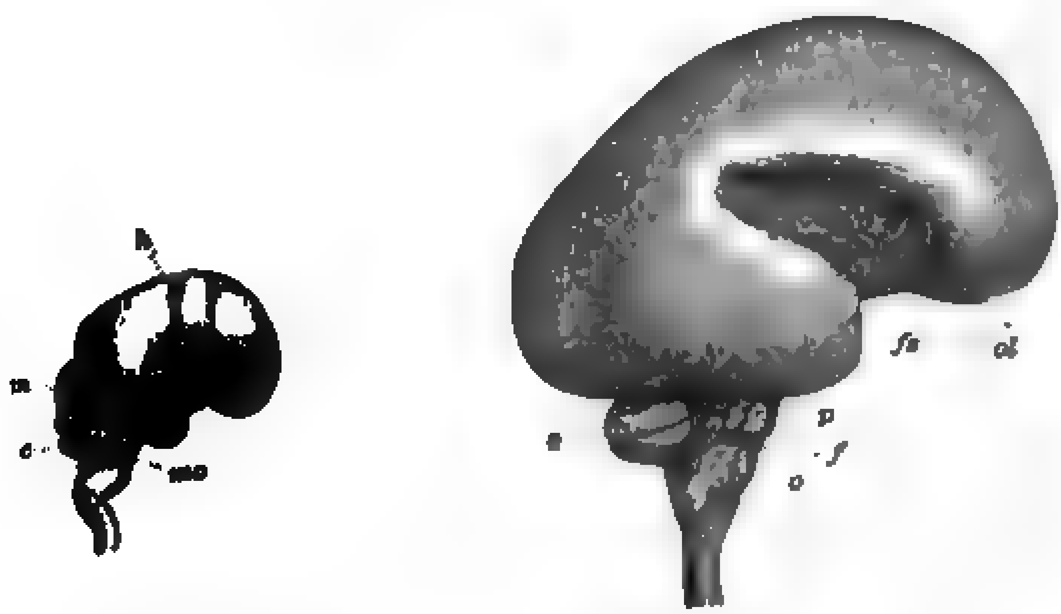


FIG. 17. — Shows development of the hemisphere, the left figure at three months, the right at six months. *fs* is the fissure of Sylvius; *c*, the cerebellum; *m*, the mid-brain. (From Kölliker.)

and cerebellum, an outgrowth of the original hind-brain. The two hemispheres are distinct from the beginning. They merely come into contact along the median fissure; there is no organic connection between them except at the base. In this growth backward, the cerebral hemispheres are folded here and there, and these folds account for some of the permanent markings upon its surface. Most striking of these is the fissure of Sylvius. This can be seen from the second month. It develops in very much the same way as the median fissure from the growing together of two outgrowths of the cerebral hemispheres. When these come into

contact on the surface, they leave considerable portions of their superficial areas in juxtaposition well below the surface. The walls of this deep fissure constitute the island of Reil.

In the course of the development, then, we find neurones originating from the cells that lined the central tube. Masses of nerve cells in the cord constitute a continuous structure. In the cerebrum and cerebellum they show an exuberant growth in comparatively isolated regions, separated from other cell masses by regions of white matter. From these cells the axones grow out for long distances to the sense organs and to the muscles on the peripheral side and to the other cell masses in central structures, until sense organ is connected with muscle, and centre with centre throughout the organism. The problem of understanding the nervous system is very largely one of tracing these connecting paths from sense organ to centre, and from centre to centre within the entire system.

**Important Facts of Nervous Conduction.** — The function of a nerve unit is to conduct something which we call the nerve impulse from the end of the dendrite to the end-brush or muscle. The question at once arises, what is it that is conducted, what is the nature of the nerve impulse? Two answers have been suggested: one, that it is an electric current; the other, that it is similar to the burning of a train of gunpowder. Five experimentally determined facts must be considered before we can draw conclusions.

1. The rate of the impulse in man is from 100 to 123 metres per second, according to Piper. This is so slow as to make it impossible to regard the nerve impulse as merely an electric current.

2. The impulse is accompanied by relatively slight fatigue. Nerves have been stimulated for several hours and will still conduct.

3. It uses very little oxygen, although oxygen is required if the nerve is to conduct.

4. Carbon dioxide is given off, but at a relatively slow rate.

5. Only extremely small amounts of heat are produced by the action of the nerve.

These facts together indicate that the energy changes in conduction are relatively slight and would eliminate the possibility that it is like the burning of a train of gunpowder. Important in any theory are the electrical changes which have been seen to accompany nervous action. Two currents are to be noticed: the current of rest and the current of action. Both may be measured by a galvanometer which connects the cut end of a nerve with its side. When the nerve is not stimulated a current passes from the side to the cut end; when the nerve is excited the current passes in the opposite direction. The cut end is negative when at rest and positive when excited. More important are recent results which show that as an impulse passes along a nerve, the excited portion is always negatively charged as compared with the unexcited portion. This negative charge moves at the rate of the nerve impulse. These results show that while the nerve impulse is not identical with the electric current, electric currents are involved in the transmission of the nerve impulse.

**The Nature of the Nerve Impulse.** — While the facts enumerated in the last paragraph eliminate the two most simple possibilities: that the nerve impulse is an electric current and that it is a transmission of a chemical change like that of the burning fuse, they show that both chemical and electrical phenomena are involved. The simplest picture is that the nerve impulse involves both chemical and electrical processes, that it is excited by a chemical change

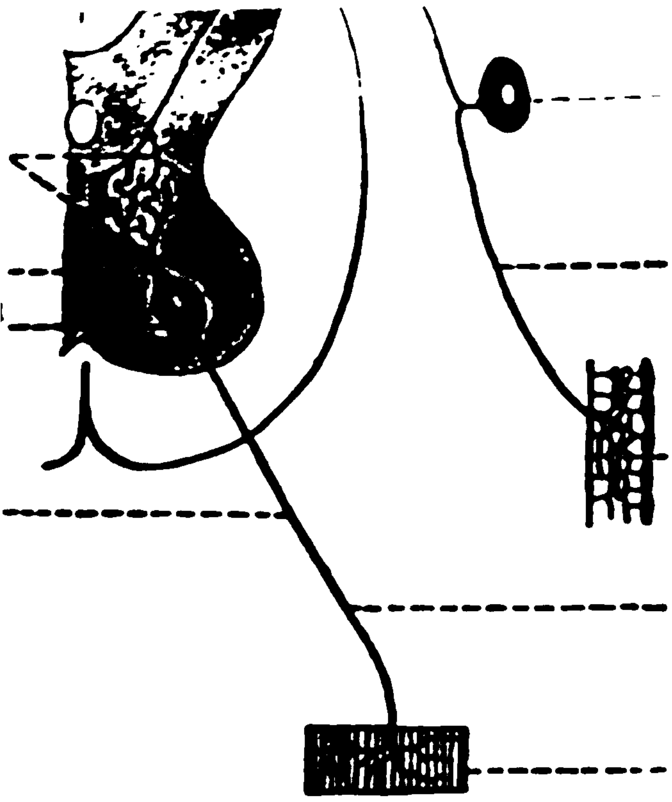
which starts short electrical currents as does the chemical action in a battery. These electric currents in turn produce new chemical changes at a short distance which again give rise to currents. Many more details need to be supplied, but there is fairly general agreement that both chemical and electrical activities are involved in the nervous impulse. Like all chemical reactions these have electrical effects and accompaniments. The chemical changes are comparatively slight but suffice to induce the electric currents. Whatever the character of this nervous impulse, it constitutes the essential activity of the neurone, and as it travels from sense organ to centre or from centre to muscle, the processes of sensation or of movement are made possible.

**The Course of the Impulse.** — The specific activities of the nervous system depend upon the course that the impulse takes through it. The simplest form of nervous response that an organism makes is called the reflex. It is the type of all nervous action. The winking of the eye, the withdrawal of the hand when burned, are primarily reflexes. The explanation of the reflex is to be found in the presence of chains of neurones between the sense organ excited and the muscle producing the response. The simplest reflex involves at least two groups of neurones, a sensory and a motor. It can be seen most clearly in the spinal cord. If a finger be pricked, an impulse passes to the cell body of a neurone in the spinal ganglion, thence along the axone to the motor cell in the front of the cord, whose activity causes the muscles of the arm to contract and draw back the hand. That these reflexes depend upon the nervous connections in the cord and upon these alone is evident from the fact that they persist in the lower animals after the cord has been cut off from the brain, but cease if the cord is destroyed or the nerves that lead to or away from it be severed. In a

frog, whose head has been removed or whose cord has been cut in its upper part, the reflexes persist. Stimulation of the skin causes movements of the members. Even a dog may be kept alive after its brain has been removed, and this 'spinal dog,' as it is called, carries on the reflex activities of the lower body in a perfectly normal way. When stimulated on the skin of one foot, that foot will be drawn back. If the intensity of the stimulation be increased, the opposite member is moved, and as the stimulation is still further increased in intensity, movements up and down the trunk at many different levels will be made. In the frog, for example, if a bit of paper be dipped in acid and put upon the skin of the right thigh, the first effect is to bring the right foot up in an attempt to wipe away the paper; if that foot be held, the other will be brought across and remove the stimulation.

## The Spinal Cord

**Reflexes in the Cord.** — To understand these reflexes as well as most of the activities of the lower part of the body it is necessary to sketch the structure of the spinal cord. The cord contains an inner mass of gray matter, somewhat like an H in shape when seen in cross section, surrounded by columns of white matter. The extensions of the gray matter are known as the horns; the backward extension, the dorsal horn, and the other, the ventral. The white matter between and around the horns comprises the columns. The dorsal horns receive axones from the spinal ganglia. The anterior horns contain large motor cells whose axones send impulses to all of the muscles. All acts, voluntary as well as reflex, are directly caused by the excitation of these cells. The white matter is divided by these horns into three columns, the dorsal, the lateral, and the ventral. In the simple




. 18.— Simple reflex connection in the $C^2$, 'T'-shaped cell in the posterior root ion; $sN$, sensory neurone; $h$, dendrite or endrion of sense organ in skin; $C^1$, motor connecting by axone $n$ with muscle $M$. n Huber.)

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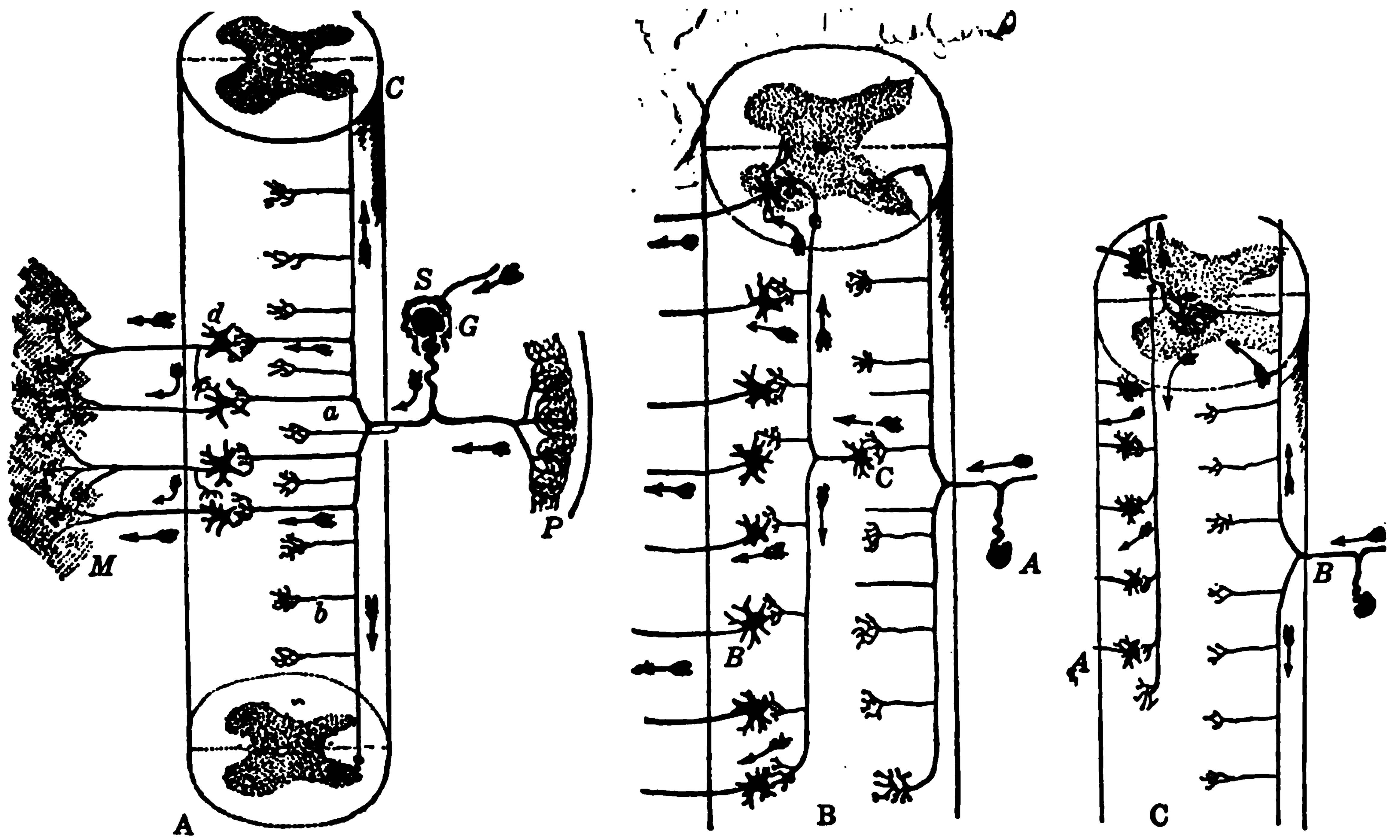
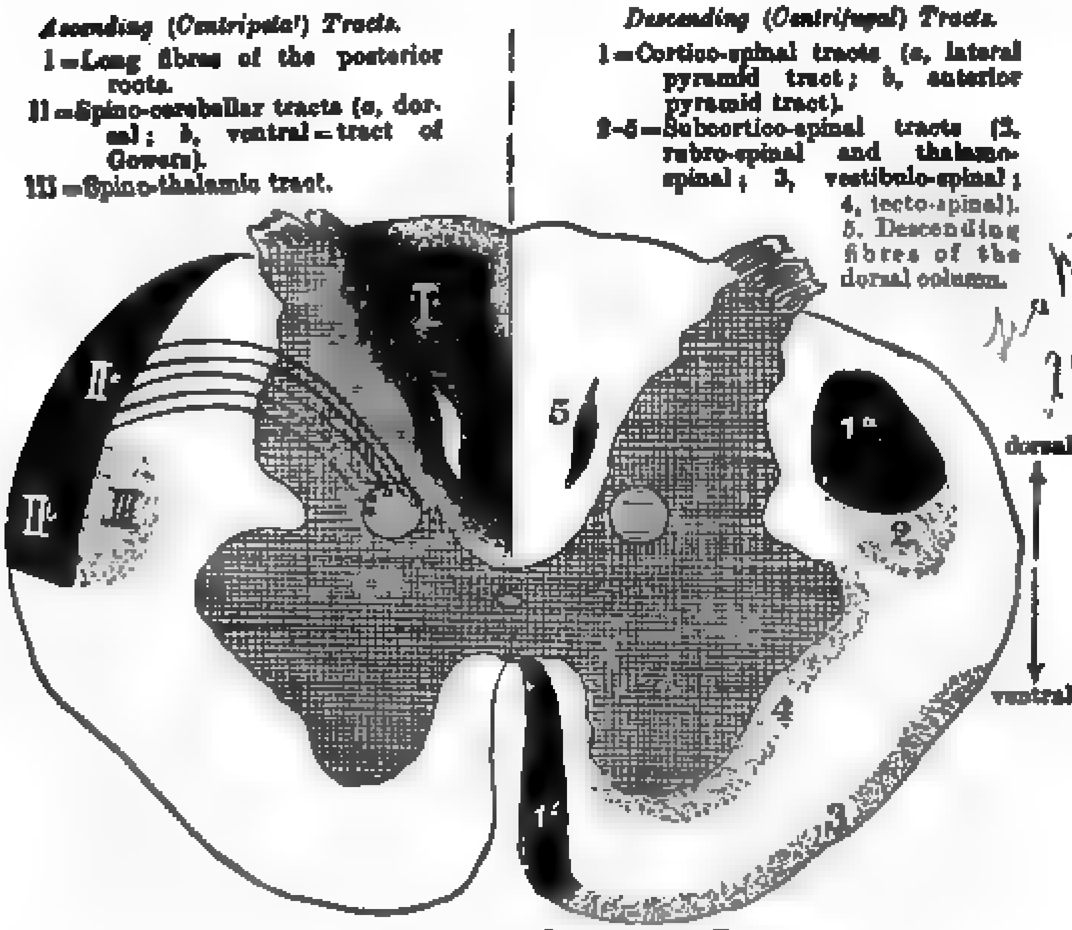



FIG. 19.—The connections in the cord by which impulses spread to different levels. *A* shows the connections by which impulses spread immediately from the sensory to motor neurones on the same side; *B* shows the connections made through an intermediate or commissural cell (*C*) to motor neurones of the same side; *C* shows paths by intermediate cell to opposite side. (From Cajal.)

various levels (Fig. 19). These make possible reflex excitation of groups of muscles above and below the point of stimulation. These cord reflexes are all to be explained in terms of the connections between sensory and motor neurones. What the response shall be is determined by the degree of openness of the synapses between different neurones.

**Tracts in the Cord.** — In addition to the reflex functions of the cord, it also serves as an important path of conduction between the periphery and the higher structures of the central nervous system, and between its own structures at different levels. The conduction paths may be divided into sensory or afferent, and motor or efferent. The sensory fibres all come, directly or indirectly, from the dorsal roots and the spinal ganglia; the motor tracts all end in the cells of the ventral horn. The different tracts are to be distinguished in terms of the higher centres to which they lead or from which they descend. The most important of the higher centres with which the cord connects are the cerebellum, which receives ascending or sensory tracts and from which motor paths descend directly and by way of the red nucleus; the corpora quadrigemina, from which small tracts descend and to which they ascend; the thalamus, to which sensory fibres go on the way to the cerebral cortex; and the cortex itself, the outer layers of the cerebrum. From this descend two tracts, whose fibres carry voluntary impulses to the muscles of the body. Of the afferent tracts, the most easily made out are the columns of Goll and Burdach on the dorsal side. These occupy most of the region between the dorsal horns. The column of Goll is nearer the centre, the column of Burdach more lateral. Each is composed of fibres from the spinal ganglia, axones of neurones in the ganglia. The only difference is that the more lateral fibres come from parts of the body on approxi-

mately the same level, which have just entered the cord; the more central have entered lower down and have been crowded toward the centre by those that come in later. Both groups of fibres end in the medulla and there make connections with neurones which send impulses to the




TOPOGRAPHY OF THE LONG SPINAL TRACTS.

Fig. 20.—Paths of conduction in cord. (From Bing's "Compendium of Regional Diagnosis." Published by Rebman Bros., New York.)

thalamus and thence to the cortex. Their chief function is to transmit impulses from the muscles. In the same area is the so-called 'comma' tract, named from its shape, which consists of collaterals from entering neurones that turn downward to connect with motor cells lower in the cord.

Other well-marked afferent tracts are found on the lateral border of the cord, the cerebellar tracts. They are divided into two, the more dorsal tract of Flechsig and the more ven-

tral tract of Gowers. Both are derived from cells in the dorsal gray of the cord and carry impulses to the cerebellum. Still another sensory tract of importance lies within Gowers' tract. It is marked spino-thalamic in Figure 20 and constitutes part of the pathway from the skin to the cortex. Sensory impulses from the skin are carried by axones from the 'T'-shaped cells in the spinal root ganglia into the gray of the cord. There they connect with a second set of neurones whose cell-bodies lie near the spinal canal. The axones from these cells cross and in part go up this spino-thalamic tract to the thalamus and thence to the cortex. The tract may also contain some fibres leading to the corpora quadrigemina.

**Motor Tracts.** — Of the descending or motor fibres the most important are found in the pyramidal tracts. There are two pyramidal tracts, the crossed and the uncrossed. The former, always the larger, lies just inside the Flechsig tract and is very close to the dorsal horn of gray matter. The uncrossed pyramidal tract lines the ventral fissure of the cord. Both tracts are composed of axones of cells in the cerebrum, which descend to make connection with the anterior horn cells. They carry the voluntary impulses. The first mentioned is composed of fibres that cross in the medulla; the second or anterior, of fibres that have continued down on the same side but cross in the cord near the level of the cells with which they connect. Other bundles descend from the cerebellum. One, coming by way of the red nucleus, the rubro-spinal (Fig. 20), lies ventral to the lateral pyramids; the other is on the ventral border. Mention should also be made of a bundle from the corpora quadrigemina, the tecto-spinal, on the ventral border of the anterior horn. It should be noted that the names applied in each instance indicate the structures connected: the

cortico-spinal tract connects cortex with cord; spino-thalamic, cord with the thalamus, etc.

In addition to these long bundles running from cells at one level to others above and below, there are many fibres which make possible the transfer of impulses within the

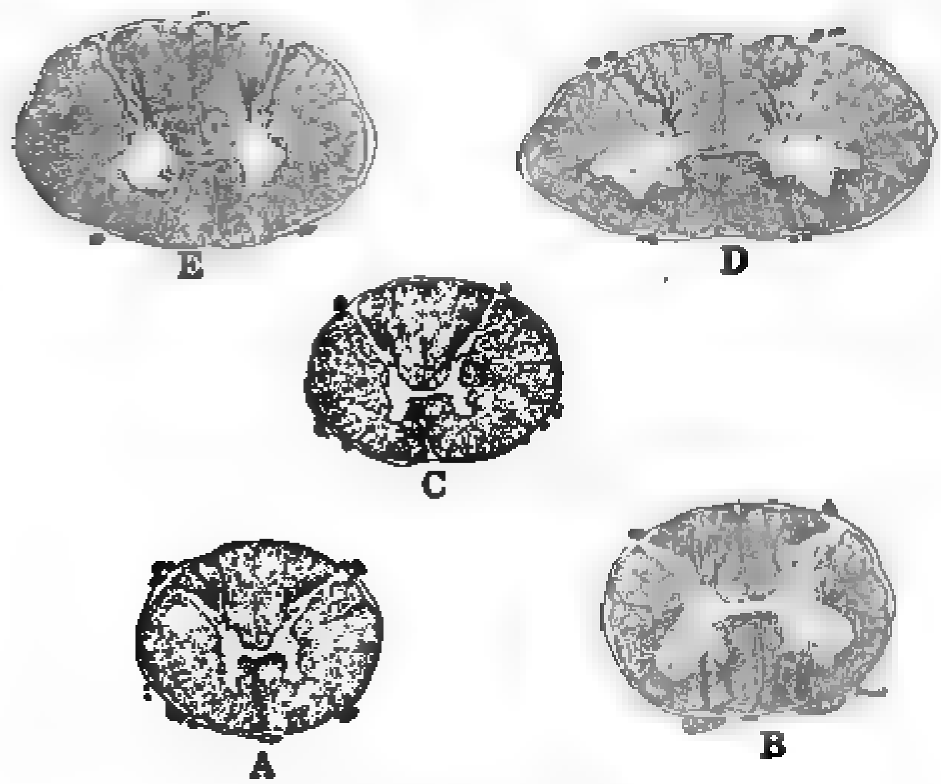



FIG. 21. — Series of sections of the cord to indicate difference in the amount of white and gray and the relative size of the cord at the different levels. *B* is a section through the lumbar enlargement, where the nerves of the legs enter and leave; *D*, a section through the cervical enlargement which supplies the arms. This figure, together with figures 23, 24, 25, and 31, was drawn by Mr. Atwell of the Anatomical Laboratory of the University of Michigan.

cord. These are numerous at the borders of the gray matter, but also occupy parts of the white area that have been assigned no other function in the above discussion. Probably some of the sensory impressions pass along these fibres on their way to the brain. They go from neurone to neurone, into the central gray and out again, instead of taking the more direct course provided by the long fibres. It should be added that the arrangement of fibres is different at different levels. The pyramidal tracts, for example, are

much larger in the upper portions of the cord, as some of the fibres that appear at the upper level leave it to make connections with the ventral horn cells. In fact, the ventral tract cannot be made out at all in the lower regions. The relative amount of white and gray matter also varies at different levels. The gray matter has the greatest extent in the lower lumbar region and in the cervical region, where the large nerves for the legs and arms enter and emerge. The cord as a whole also increases in cross section from below upward, with marked swellings where the large nerves enter. See Figure 21.

## The Brain Stem

**Functions of the Brain Stem.** — In the brain stem, from the medulla upward, the structure of the nervous system becomes much more complicated, but the functions and general arrangements are much the same. We may distinguish three functions of the structures in the brain stem:

1. Fibres massed in well-defined tracts carry the sensory impressions upward and motor impulses downward between cord and cerebrum.

2. Masses of neurones care for the reflexes of the head in very much the same way that the cord cares for those of the body. Nerves lead into them from the special sense organs and from the skin of the head, and motor nerves lead out from them to the muscles of the head just as sensory nerves lead into, and motor nerves go out from, the cord.

3. The brain stem also makes wider interconnections, — serves to combine large numbers of sensory stimuli from different sense organs and to combine and distribute them in exciting muscles in widely scattered parts of the body to make harmonious movements.

Making the different parts of the body work together is the peculiar function of the nervous system. The coördinations in the brain stem are wider than those in the cord and those of the cerebrum are widest of all.

**Important Structures in the Brain Stem.** — To trace the ascending and descending paths of impressions, we need to distinguish several structures in the brain stem that serve as way stations, points where impulses are transferred from the axone of a lower neurone to the dendrites of a neurone that carries them upward, or where descending impulses are interrupted and transferred to new neurones. The first are in the medulla, the so-called nuclei of Goll and Burdach (Figs. 23, 24). These, with the thalamus, are parts of the pathway of sensory impulses from the trunk and limbs. The thalamus is a structure at the base of the cerebrum which can be seen in a median section of the nervous system on the walls of the third ventricle, or from above in Figure 22. Below it to one side may be seen the internal and external geniculate bodies, and still lower lie

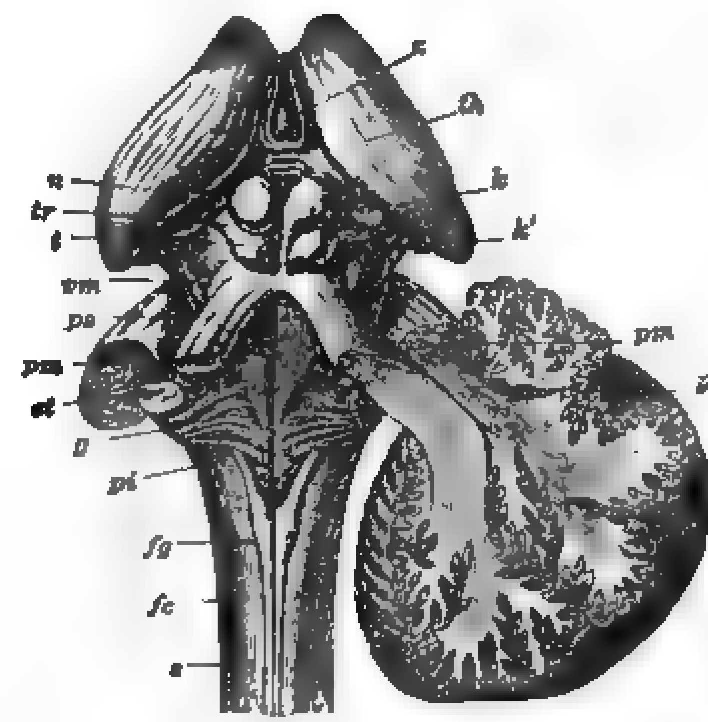



FIG. 22. — Dorsal view of brain stem. *fg*, column of Goll; *fc*, column of Burdach; *n*, anterior, *t*, posterior pair of corpora quadrigemina; *th*, thalamus; *k*, external and *k'* internal geniculate bodies; *z*, epiphysis (pineal gland); *ps*, *pm*, *pi*, are superior, middle, and inferior peduncles of the cerebellum, which may itself be seen, in part cut away and drawn to one side. (From Wundt)

the corpora quadrigemina. These are both receiving organs for certain of the fibres from eye and ear, and will be mentioned in connection with these sense organs. The red nucleus lies within the body of the brain stem below the back portion of the thalamus and the corpora quadrigemina (Fig. 31). This is a way station from the cerebellum and also from the cortex to the cord. A part of the cerebellum can be seen drawn to one side in Figure 22 and the pons is

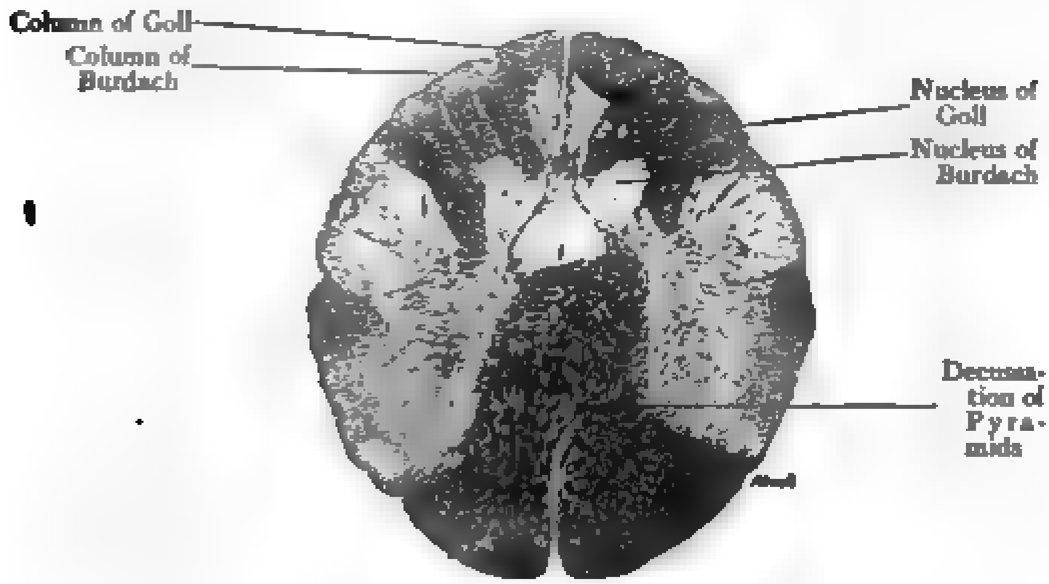



FIG. 23. — Section of the medulla to show the crossing of the pyramidal tracts, a section a little below that shown in Figure 24. × 4.

directly in front of it. For our purposes these are the most important structures in the brain stem.

## THE PATHS IN THE BRAIN STEM

**The Paths between Cord and Cortex.** — Nerve currents from the sense organs of the limbs and trunk may reach the cortex by two distinct paths. The first, which probably carries only the impulses from the muscles and other deeper lying tissues, is provided by the columns of Goll and Burdach. Axones of cell bodies in the spinal ganglia ascend by these tracts to the nuclei of Goll and Burdach. Here they come into contact with dendrites of other neurones

whose axones cross to the other side and then proceed up the central portion of the brain stem to the thalamus. Thence a third set of neurones carries the impulse to the cortex. Impulses from the external skin apparently travel by other spinal neurones whose axones enter the central gray of the cord and make connections with dendrites of a second neurone whose cell body lies near the central canal.

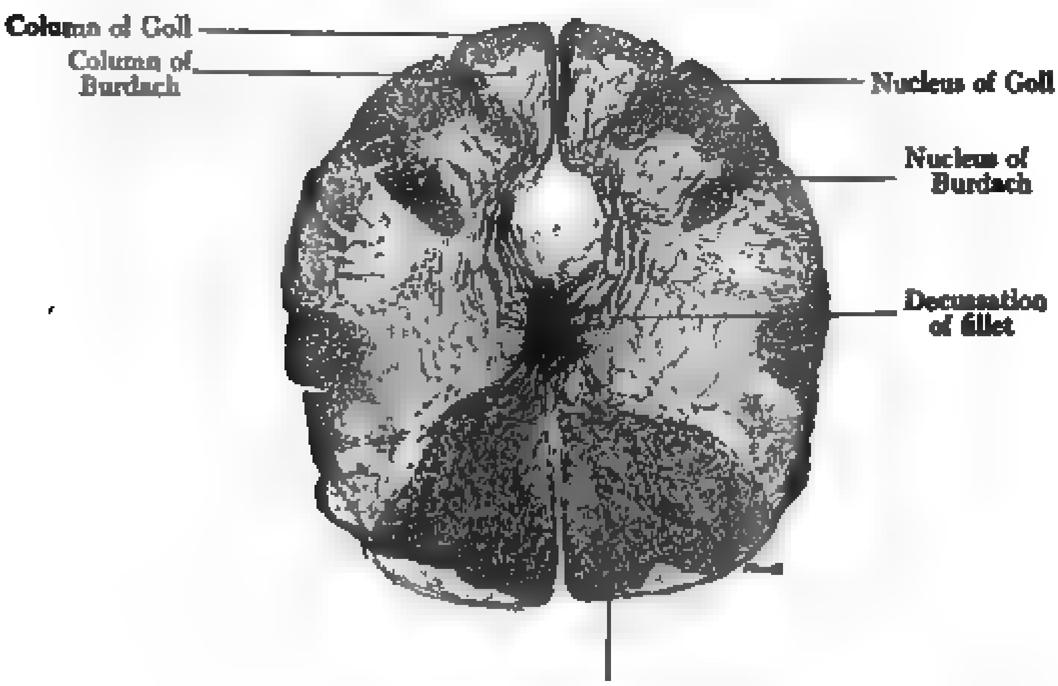



FIG. 24. — Section through the medulla to show the crossing of the sensory fibres, the axones of cells in the nuclei of Goll and Burdach. × 4.

These neurones send their axones up the lateral column of the opposite side to the thalamus. The exact path that is followed in the lateral column is not definitely agreed upon. Some authors believe that there is a long tract in the anterior portion of the lateral column, the spino-thalamic tract in Figure 20; others that the path goes by way of short fibres near the gray and perhaps may be interrupted at different levels. The axone may reënter the central gray several times, connect with a new neurone, and have that neurone continue the impulse upward. That there is

a pathway upward on the side of the cord opposite to that of the sensory nerve stimulated, and that this carries the cutaneous impulses, is made very probable by observation of pathological cases. Figure 26 shows the posterior paths. The descending tracts from the cerebrum are the pyramidal tracts. The fibres that compose them are axones of cells in the motor cortex. They can be traced on the anterior

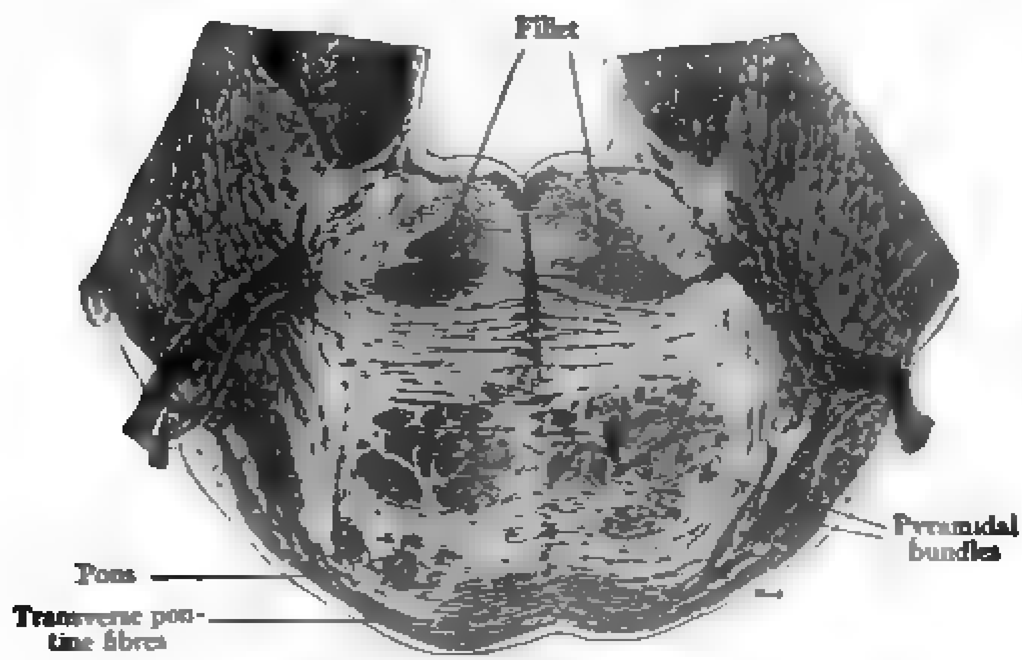



FIG. 25. — Section through pons. The interlacing of the descending pyramidal tracts, with the cross fibres of the pons, mainly connecting the lobes of the cerebellum, is clearly shown. Above, dorsal to the pons, may be seen the section of the fillet, the sensory fibres ascending from the nuclei in the medulla to the thalamus. A section of part of the fifth nerve may also be seen.

portion of the brain stem through their whole course except where they intermingle with the fibres of the pons, as can be seen in Figure 25 (a section through the pons). In the medulla, part of the fibres cross, as can be seen in the cross section, Figure 23. These constitute the crossed pyramidal tracts already noticed in the cord. The uncrossed pyramidal tract, which is usually smaller, and may not be present at all, continues down the anterior column and crosses in the cord at the level of the anterior horn cells

with which it is to make connection. The right hemisphere of the cortex therefore always arouses movements in the left half of the body, and *vice versa*. The course of these descending fibres also can be seen in Figure 26. Only two neurones are required to transmit the motor impulse from the cortex to the muscle, while three at least are concerned in carrying the sensory impulse upward.

**Roots of Cranial Nerves and their Central Connections.** — The brain stem is like the cord, also, in its second set of functions, receiving sensory fibres and impressions, and sending out motor nerves and impulses. Unlike the continuous series of cells in the cord, the cell bodies whose dendrites

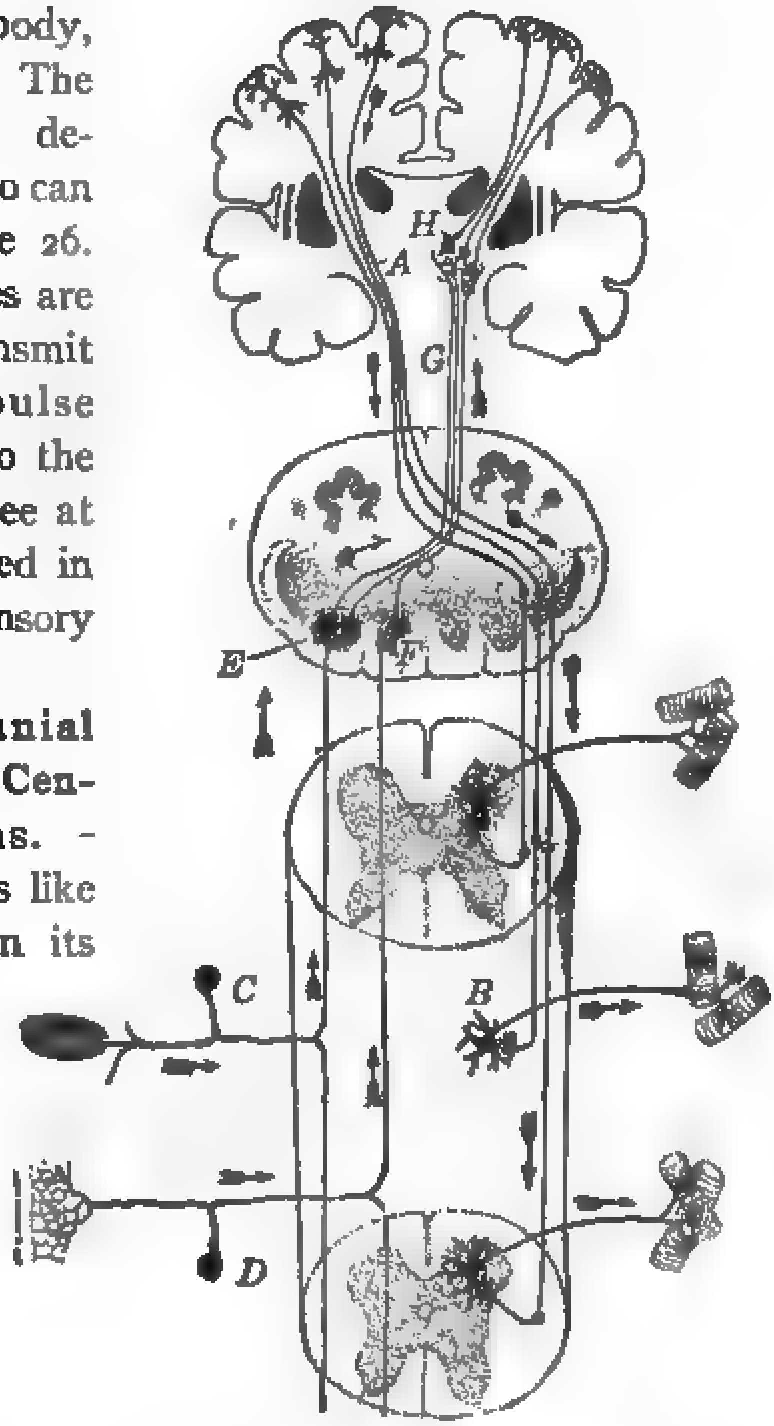



Fig. 26. — Showing schematically the ascending and descending tracts between cord and cortex. *A*, pyramidal tracts; *B*, motor cell; *C*, *D*, sensory cells; *E*, *F*, nuclei of Burdach and of Goll; *G*, central sensory path; *H*, thalamus. Only the sensory path by the posterior columns is indicated. The arrows indicate the direction of the impulse. (From Cajal.)

and axones constitute the so-called cranial nerves are grouped in isolated masses of cells along the brain stem, the nuclei of the cranial nerves. From these nuclei, connections are made with each other, with the cerebellum,

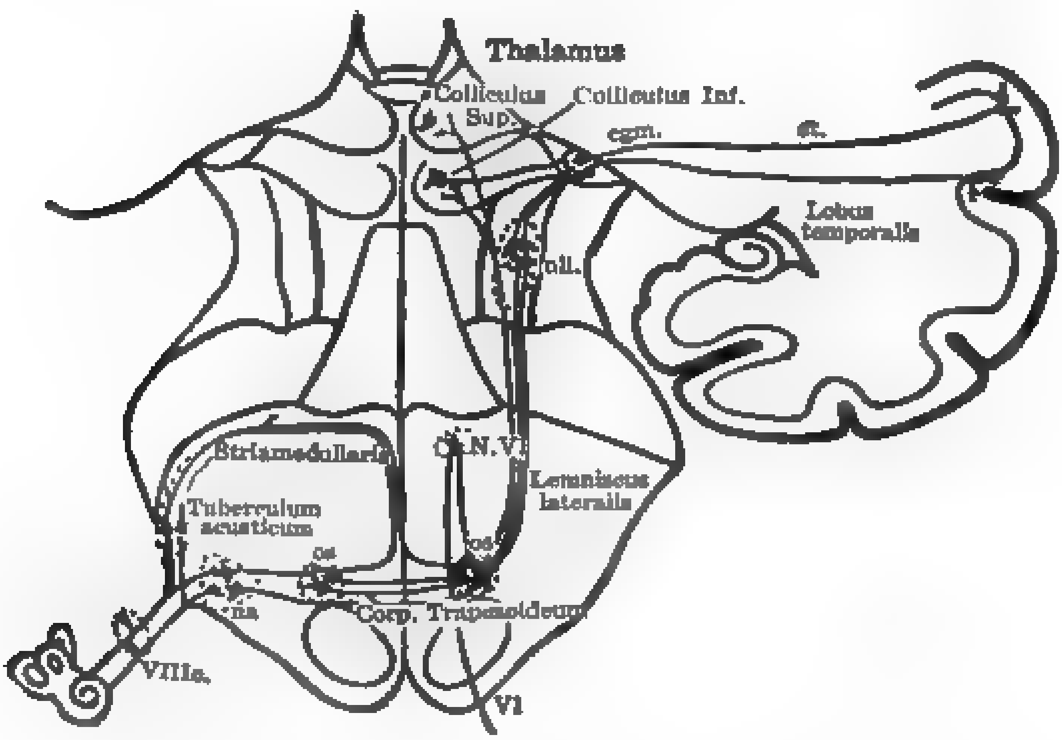



Fig. 27 — The central connections of the cochlear branch of the eighth nerve, the nerve of hearing. The first layer of neurones have their cell bodies in the spiral ganglia (VIII c) which correspond to the spinal root ganglia of the cord. Their axones connect with a second layer of neurones either in the ventral root of the eighth nerve (*na*) or in the tuberculum acusticum. The axones from this second layer of cells in both nuclei go to the superior olives (*os*), some to the one on the same side and some to the one on the opposite side. From the olives third neurones connect with a fourth layer of neurones with cells in the nucleus lemniscus lateralis (*nll*) which carry the impulses to the internal geniculate bodies (*cgm*) and thence by a fifth layer to the temporal lobe of the cerebrum. Certain of the neurones in the olives send axones to the inferior corpora quadrigemina (*colliculus inf.*) where reflex connections are made with motor roots of the brain stem. (From Rauber-Kopsch.)

corpora quadrigemina, and cortex. The location and connection of the parts would require more space and the knowledge of more details of anatomy than can be given in so brief a treatment. It may be said in general that there is some approximation to the arrangement of the

spinal cord in that the motor nerves frequently are anterior to the ventricles, while the sensory roots are more lateral or posterior. These sensory and motor nuclei also have connections with the cortex similar to those of the cord.

**Connections of the Auditory Nerve.** — We may trace the course to the cortex of some of the more important sensory nerves of the head. The eighth nerve, or nerve of hearing, consists of the axones from the cells in the spiral ganglia in the ear (Fig. 27). These connect with the dendrites of cells in the root of the eighth nerve at the level of the pons; from these, new neurones carry the impulse to the superior olives on both sides, and thence by two other neurones it goes forward to the internal or median geniculate body, a body near the thalamus, and to the posterior corpora quadrigemina. From the geniculate body, one set of neurones carries the impression forward to the cortex where hearing takes place. In the posterior corpora quadrigemina reflex connections are made with ear and head muscles.

**The Optic and Cutaneous Tracts.** — The optic tract is very similar (Fig. 28). The axones from the eye enter the external geniculate body and possibly the visual area of the thalamus, thence go to the cortex. The fibres that control the eye reflexes and the higher coördinations run directly to the anterior corpora quadrigemina, where they make connections with nuclei of the motor nerves to the eye. The fifth nerve, in part a sensory nerve for impressions from the skin and other tissues of the head, has its cells in a large ganglion, which has much the same relation to the brain stem that the dorsal root ganglia have to the cord. Thence axones connect with second neurones in the nucleus whose axones go to the thalamus, whence the third neurone makes connection with the cortex (Fig. 29). In

general the fibres of all these nerves cross either in the brain stem or, in the case of the eye, whose fibres cross in part only, in the optic nerve itself. The fibres from the

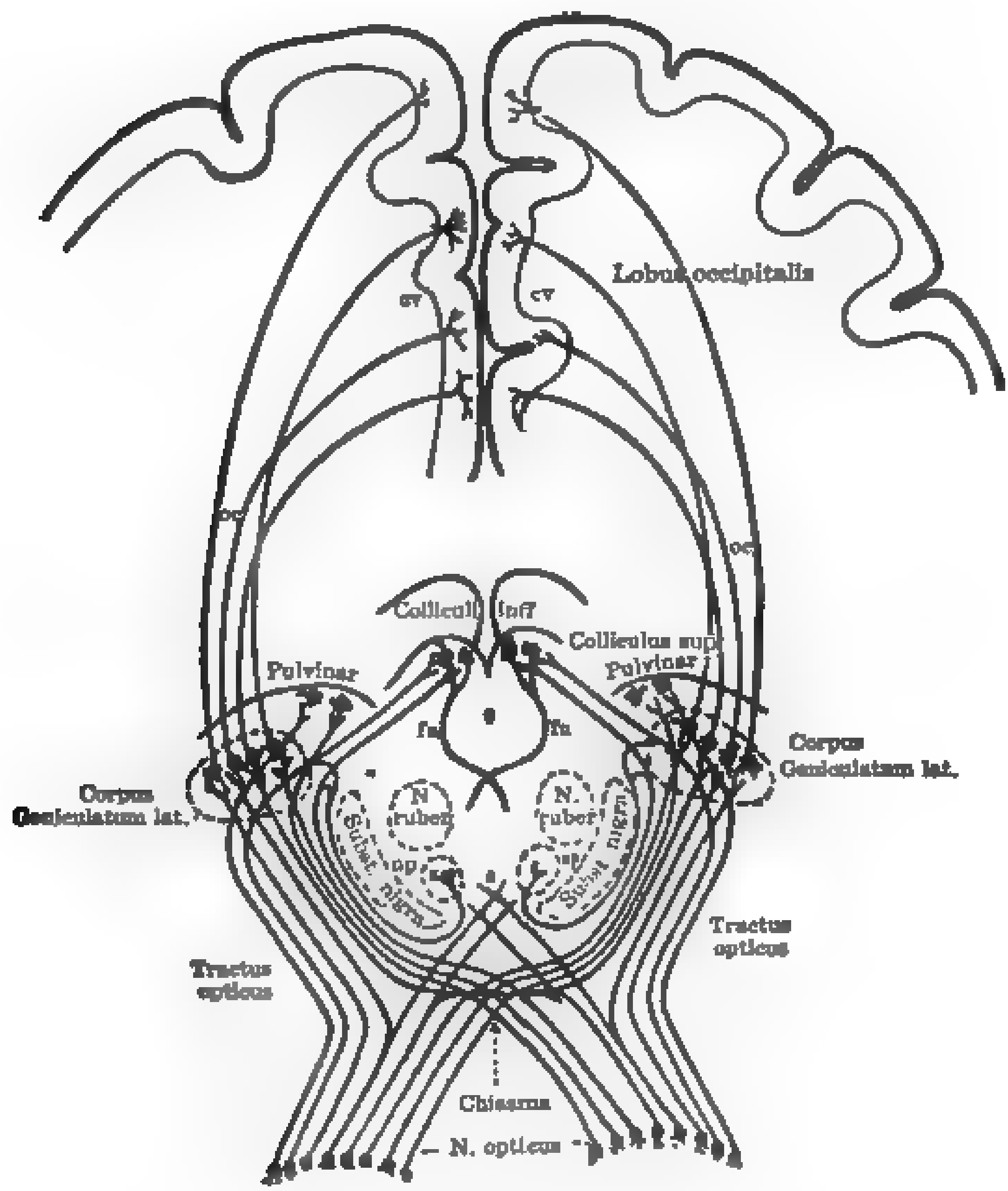



**Fig. 28.** — The central connections of the optic nerve. From the neurones in the eye the axones that form the optic nerve extend, after partial crossing in the chiasma, to the external geniculate body where connection is made with a second series of neurones which carry the impulse to the median surface of the occipital lobe. Other axones connect with the pulvinar of the thalamus and with the anterior corpora quadrigemina (*Colliculus sup.*). From the latter impulses are carried to the roots of the oculo-motor nerves by the path *fa*, through which reflexes are aroused. (After Bechterew.)

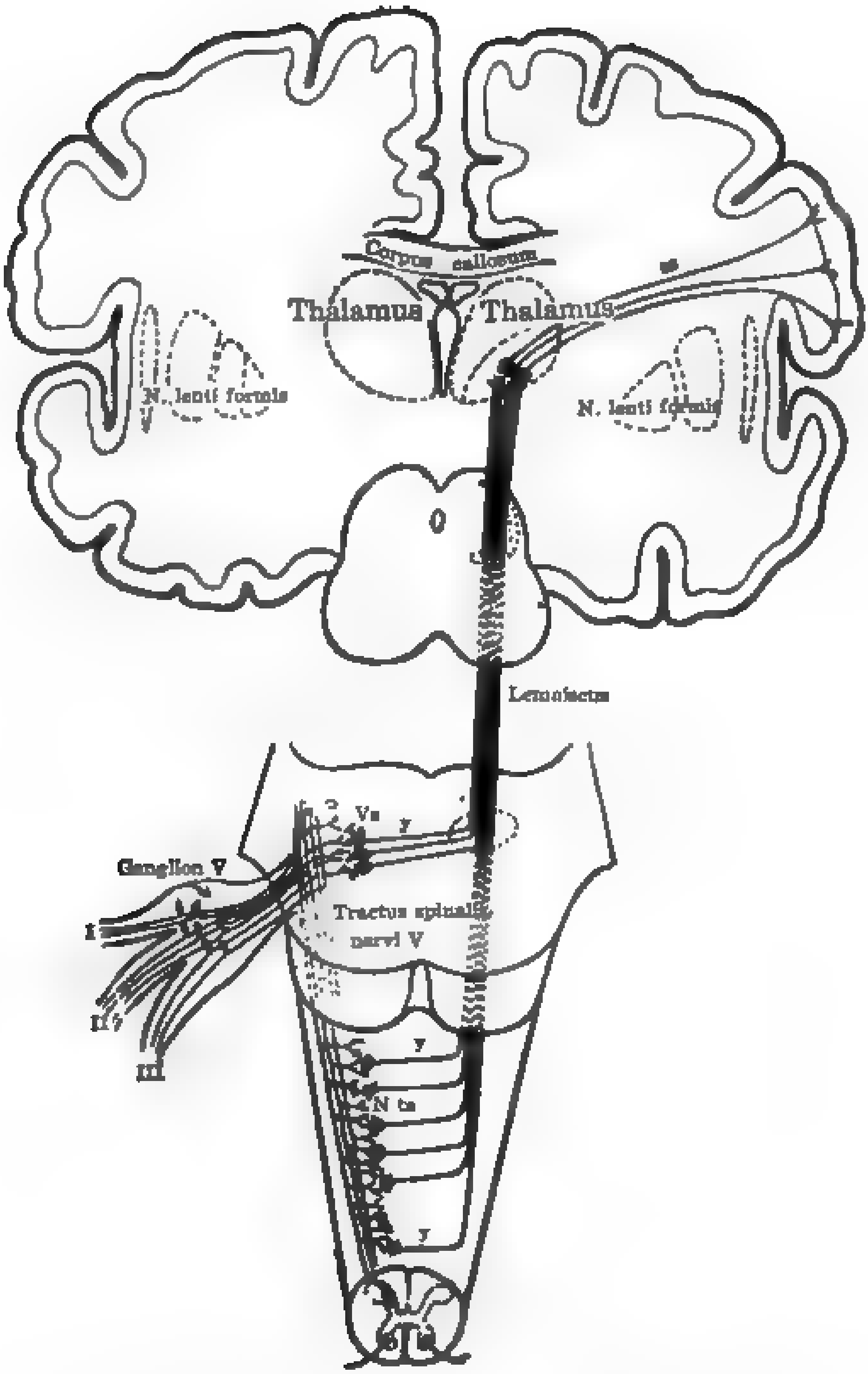



FIG. 29. — The ascending or sensory connections of the fifth nerve. The relations are very similar to those of the dorsal roots of the cord. The receiving neurones have cells in the ganglion (*Ganglion V*), send axones to the sensory nuclei, *Vs*, which correspond to the nuclei of Goll and Burdach for the spinal nerves, whence the new neurones connect with a third layer of neurones whose cell bodies are in the thalamus and which carry the impulse to the cortex. (From Rauber-Kopsch.)

inner halves of the retinas cross, and finally reach the cortex on the opposite side; those from the outer halves go to the cortex on the same side. Corresponding to the pyramidal fibres that descend to the cord, motor fibres also descend from the cortex to the roots of the motor nerves of the head and make possible the voluntary control of the eyes, tongue, facial muscles, etc.

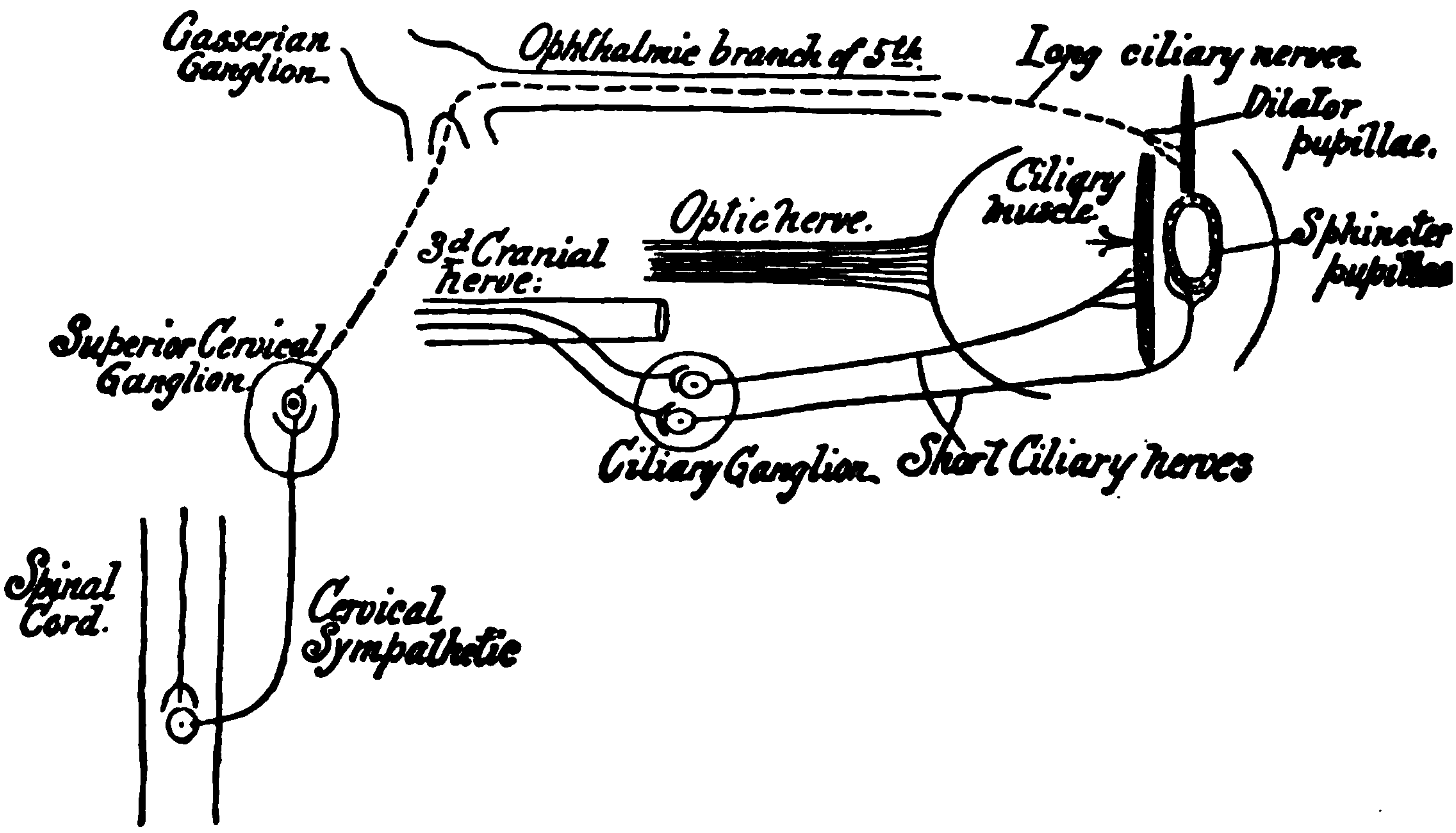



FIG. 30. — The reflex control of the size of the pupil. The impulse of dilatation takes the long path from the corpora quadrigemina down to the cord and back through the cervical sympathetic, the superior cervical ganglion, and out through a branch of the fifth nerve to the iris. The impulse to contraction makes connection through the third nerve with the ciliary ganglion, thence to the iris. (From Howell's "Physiology," after Schultz.)

The reflex function may be illustrated by the contraction of the pupil in a bright light. As was said above, the optic nerve sends one branch to the anterior corpora quadrigemina. Thence axones proceed to the roots of the third nerve. Neurones there in turn connect with the ciliary ganglion back of the eye, which sends the impulse to the circular muscle in the iris. Strong light causes the sensory impulse to ascend to the corpora quadrigemina, whence it is transmitted by a new neurone to the motor nucleus,

thence, through at least two more neurones, to the muscle of the iris, whose contraction diminishes the diameter of the pupil (Fig. 30). Similar reflexes are seen in sneezing, which involves the spinal cord as well as the brain stem; in making a wry face at a bad taste, etc. In the medulla are the reflex centres that control respiration, circulation, and other vital functions. The details of the paths, so far as known, may be obtained from any good physiology.

## Cerebellum, Corpora Quadrigemina, and Thalamus

**Connections of the Cerebellum.** — The third or coördinating function is most highly developed in the cerebellum and corpora quadrigemina. If we consider the connections of the cerebellum, it becomes evident that it is closely connected with the adjustment of movements. To it, as we have seen, go two sensory tracts from the cord. To it also go fibres from the vestibule of the ear, the organ for appreciating the position of the body as a whole. It receives fibres from the cortex and fibres from the ocular tracts. From it go fibres to the spinal cord directly and by way of the red nucleus in the mid-brain just below the corpora quadrigemina. It also sends fibres to the motor nuclei of the eye muscles. These make possible the movements of the muscles of the trunk and head.

**The Function of the Cerebellum.** — The general function of the cerebellum is to coördinate muscular movements, particularly those involved in keeping the balance. The influence is best evidenced by the defects that appear when the cerebellum is injured. Then the body is held erect only with difficulty, if at all, the movements are jerky, the patient staggers when walking, the gait is like that of the drunken man. The balance of the body is not adjusted to the movements of the legs, the patient may lean

too far forward or too far back for the immediate position of the body. Recent work makes it probable that certain parts of the cortex of the cerebellum take care of definite parts of the body. Streeter has established the localization by tracing the fibres, Bárány by a study of the effects of injuries of the cerebellar cortex and by direct stimulation of its surface. It is probable that the nerve currents from

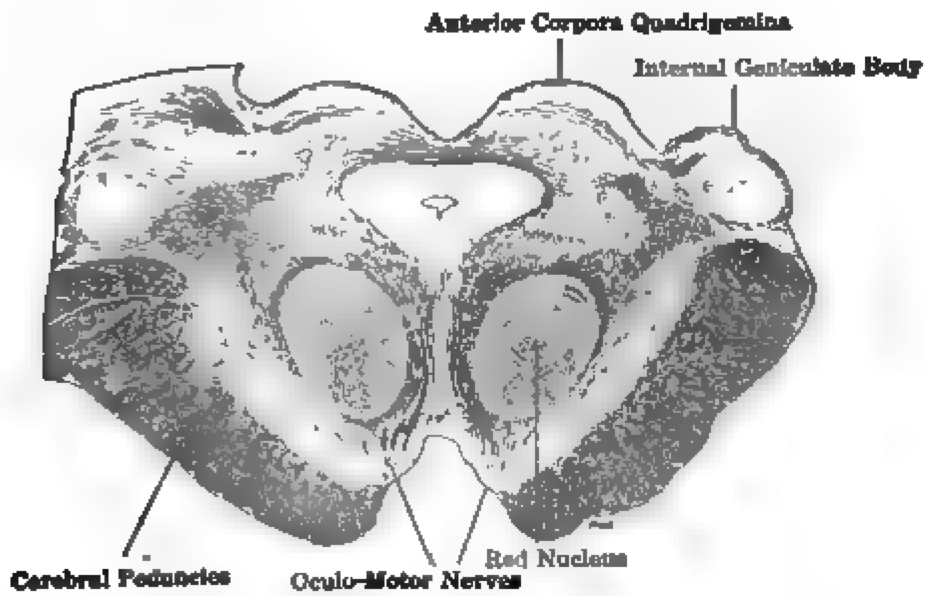



Fig. 31. — Section of mid-brain to show position of red nucleus. The anterior corpora quadrigemina and the internal geniculate bodies can also be seen, as can the fibres of the third nerve, whose roots receive fibres from the corpora quadrigemina on the way to the eye muscles. In the lower anterior portion the descending fibres that constitute the cerebral peduncles may be seen. The pyramidal tracts are in the median portion of this structure. × 2.

the various organs, skin, muscle, the vestibules of the ears and the eyes, which give a knowledge of position, are here united and coördinated and then sent out to the muscles, where they produce the muscular contractions that keep the balance. The cerebellum thus serves to bring together the sensory impressions concerned in movement, to graduate them properly, and to send out impulses which shall control the lower reflexes, check some, increase others, and make all work together in proper balance.

**Functions of Corpora Quadrigemina.** — From the fact that the corpora quadrigemina receive fibres from skin, ear, and eye, and have connections with the motor cells in the cord, as well as with the eye muscles and other muscles of the head, it seems probable that this may be a similar coördinating centre. In the lower animals the large development of these organs, as compared with the other regions of the brain, together with direct experiment, make it seem likely that many of the automatic movements are coördinated here. In man, however, this lower centre of coördination has been largely overshadowed in its functions by the cerebral hemispheres, so that it plays a subordinate part. It is the centre for reflexes of the eyes, and probably for movements of the head, but neither experiment nor pathology gives much evidence of a coördinating function.

**The Functions of the Thalamus.** — We have seen that the thalamus is a way station for impulses from the skin and other sense organs in their course to the cortex. Recently evidence has been accumulating that it is also closely connected with emotional expression. In emotion there are changes in the circulation, in the expression of the face, and the secretions in certain of the glands. These responses seem to be produced reflexly through the thalamus. When the thalamus is injured the responses are changed. Bechterew reports a case in which injury to one thalamus destroyed the emotional expression of one side of the face and left the other undisturbed.

REFERENCES

VILLIGER: Brain and Cord.
HERRICK: Introduction to Neurology.
HOWELL: Physiology, Chs. VI, VII, VIII.
STARLING: Physiology, Ch. VII, §§ vii–xvi.

# CHAPTER III

## THE NERVOUS SYSTEM (*Continued*)

In the cerebral hemispheres we come much closer to the problems that primarily concern psychology. Here, we believe, the processes which accompany consciousness in all its forms have their place, and run their course. But for an understanding of the nervous operations themselves this makes no difference. The structures and their functions can be best understood on the analogy of the lower parts of the nervous system. It is in its turn just a mass of neurones with their processes, and its functions can be represented as due to the spreading of impulses along paths within it. The problems that meet us here are those that have met us all the way up to this point. The cerebrum constitutes part of the highest and most complicated path by which sensory impressions may pass over to the muscles and excite muscular contraction.

### The Functions of the Cerebrum

**The Parts of the Cerebrum.** — In the cerebrum may be distinguished three sets of structures. On the surface there is a relatively thin layer of gray matter, a number of layers of neurones with connecting processes, — the cortex. This outer coat has a large surface because of the great number of fissures and folds that are found on its surface. These are much more developed in man than in the animals. Below the cortical gray the interior is largely filled with white matter, — masses of fibres that run from the cortex down-

ward to the brain stem, from one part of the hemisphere to another, or from one cortex to the other through the corpus callosum and the commissures. At the base of the cerebrum are found other masses of gray matter, the corpora striata. These are divided into a number of masses by the fibres that descend from the cortex to the brain stem, the corona radiata. The function of the ganglia at the base of the cerebrum has not been definitely determined. They have connections with the centres in the brain stem, but relatively few with the cortex. It has been supposed that they have something to do with the regulation of the temperature of the body. We need not consider them farther.

**Lobes of the Cerebrum.** — The cerebrum is divided by the median fissure into two hemispheres. Each hemisphere for convenience of reference has been divided into five lobes. Three fissures in the cortex have been selected as boundaries. The most prominent is the fissure of Sylvius. It is on the side of the cerebrum and runs backward and upward from a point under the skull on a level with the eyebrows. Although the edges of this fissure are in contact, there is usually a considerable hollow below the surface, and its sides and bottom have a considerable area. This area is called the island of Reil and is usually spoken of as one of the five lobes. From a point near the middle of the Sylvian fissure, a second prominent fissure extends upward and a little backward to the median fissure and often shows on the median surface of the hemispheres. It never extends quite to the fissure of Sylvius, but is separated from it by a fold or gyre. The fissure itself is the central fissure, or fissure of Rolando. The central fissure marks off the frontal lobe from the parietal behind it, and the Sylvian fissure separates the frontal and parietal from the temporal lobes. The parietal lobe is bounded at the back by the occipital lobe.

The line of division is distinct on the median surface of the cerebrum, the so-called parieto-occipital fissure, but no boundary is to be noted on the lateral surface. The line of demarcation between the parietal and temporal lobes

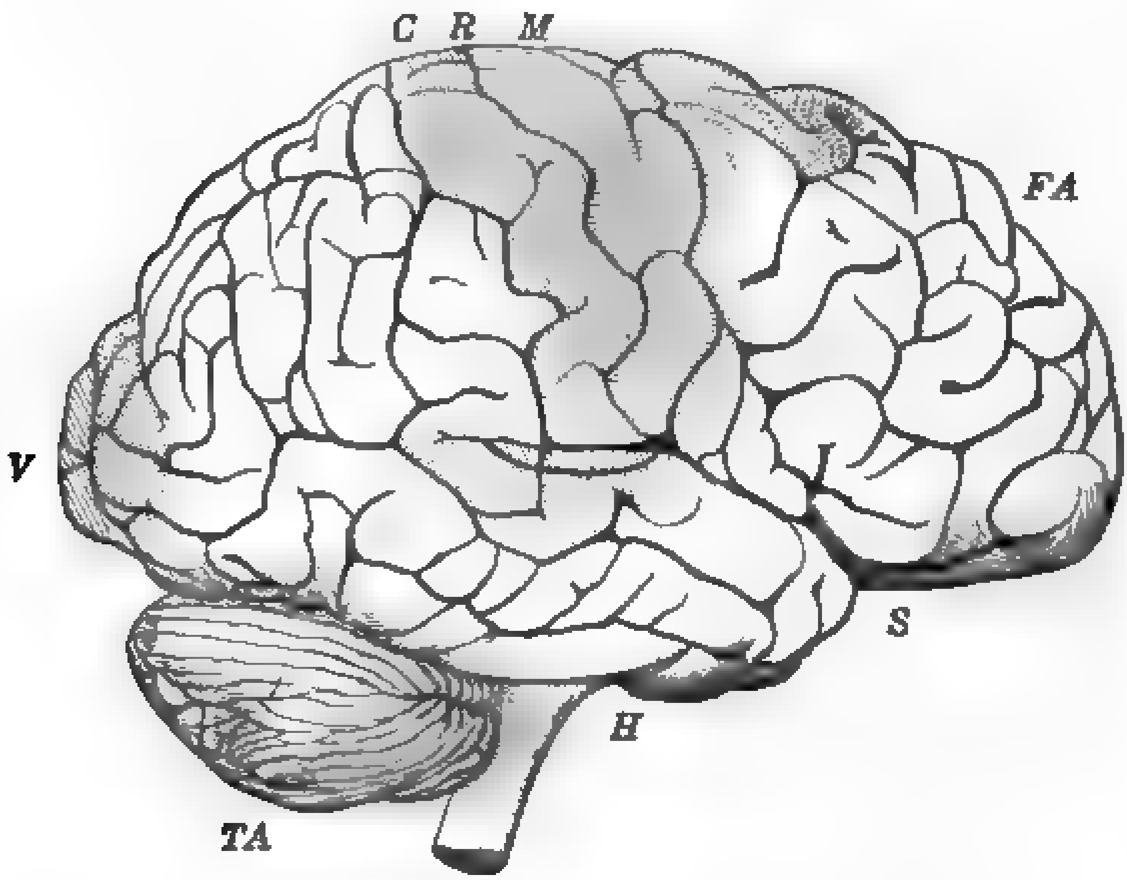
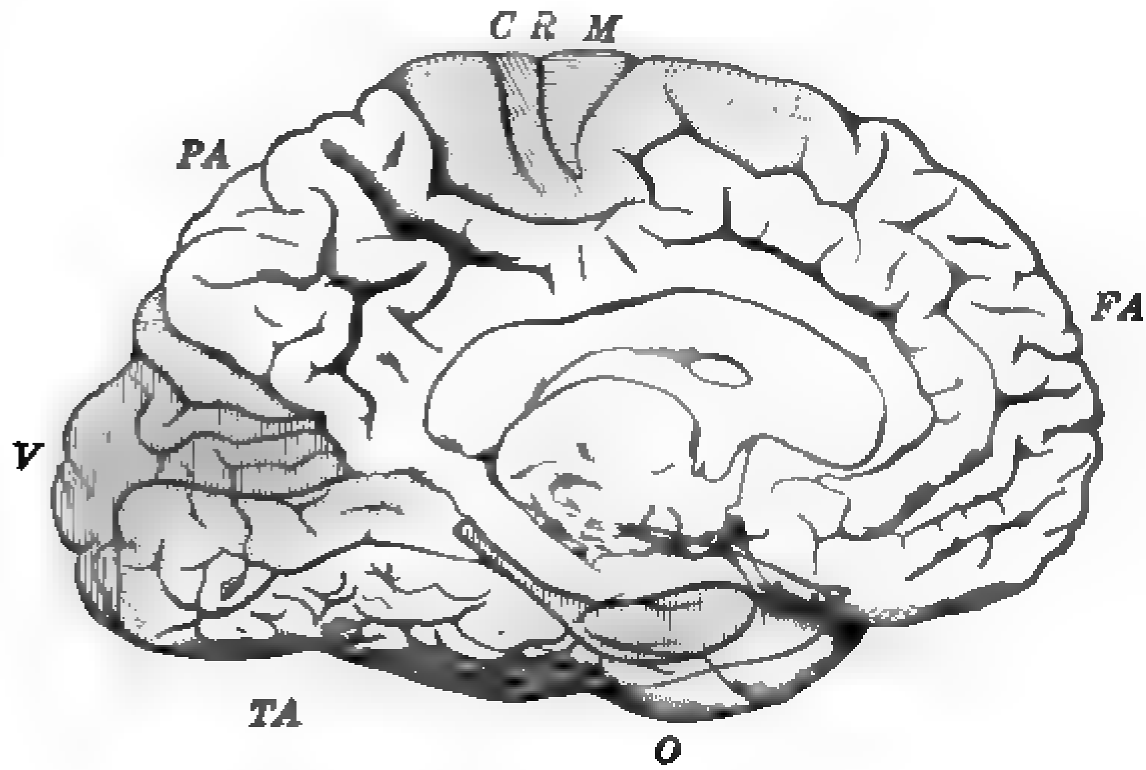



FIG. 32 — Localization of cerebral functions. The figure above shows the outer surface of the right hemisphere; the one on p. 63, the mesial surface of the left hemisphere. In both figures the motor areas are marked by horizontal shading, the sensory by vertical shading, while the associatory areas are unshaded. The doubtful or partially sensory and motor areas are dotted. *S* is opposite the fissure of Sylvius; *R*, above the fissure of Rolando. On the mesial surface the parieto-occipital fissure is just above the shaded portion marked *V*; *M* is above the motor

is a line continuing the Sylvian fissure. It should be stated that the fissures and gyres are not the same on different brains. The Sylvian fissure can be recognized in every case, the central fissure in practically every case, but the others are subject to considerable variation. The five lobes, the frontal, temporal, parietal, and occipital, together with the island of Reil, are the parts into which the cerebrum is

divided. The two important reference lines are the fissures of Sylvius and Rolando. They can all be made out in the diagram (Fig. 32).

While the functions of the cerebrum stand in closest connection with thought and with mental operations in general, the development of a knowledge of the exact connection




area; *C*, above the cutaneous and kinæsthetic area; *V* indicates the visual area; *O* is below the olfactory area. The auditory area is just below the fissure of Sylvius, above *H*. *FA* designates the frontal, *PA*, the parietal, and *TA*, the temporal association areas. There is some evidence that the dotted areas about the sensory and motor areas are areas in which particular associations are formed for the corresponding sense or movements. (The diagram embodies the results of A. W. Campbell, but has been modified in one or two respects to agree with the results of Flechsig and Cushing.)

between the parts of the cerebrum and mental action has been a matter of very slow growth. The phrenologists, Gall and Spurzheim, began it, but their methods were very inaccurate and their conclusions so much mixed with speculation that hardly any progress was made. After their time, in the third decade of the last century, through the work of

Flourens, the opinion became fully established that the cerebrum acted as a unit, and no function could be assigned to one part rather than another. It was not until 1867 that Broca's studies of aphasia gave a suggestion that each part of the cortex has a special function, and led to studies of localization. Since 1890 the localization has been generally accepted. The only problem has been to determine how far the different parts interact in a given function.

**Methods of Studying Localization of Function.** — The methods that have thrown light upon the subject fall in general under three heads, — experiment, observation of the effects of disease, and study of the paths and anatomical structure of the different regions. Experiments were early performed on the lower animals, in particular upon monkeys and apes, whose brains most nearly approach those of man in structure. Parts of the brain were extirpated, and when the animal had recovered from the shock of the operation, its movements were studied to see what change the operation had made. Again the brains of animals were exposed and the cortex stimulated by electric currents and the resulting movements were noted. In man, cases of mental defects, whether sensory or motor in character, were studied carefully and then the brain of the patient examined after death and the two series of results brought into connection with each other. It was found, for example, that a man who showed one sort of difficulty in speech would have lesions in one part of the brain, a man with another sort of defect would have another area diseased. Careful study of many cases has shown that there is a close relation between the two. The anatomical methods have resulted in tracing paths of connection between many areas, and have shown some relations that could not be demonstrated by either of the others. One method of this character that

has given noteworthy results was introduced by Flechsig. He found that the different connecting paths in the brain became medullated successively as the nervous system developed, and by a method of staining brains at different ages, he was able to make one path stand out clearly among all of the others and to follow its connections with ease and certainty. Even more recently study of the cells, and of the arrangement of cells and fibres that make up different areas, has shown that areas which differ in function differ also in their finer structure.

As a result of these methods, we feel assured that the cortex is the part in which the final coördinations take place and which is most closely related to consciousness. We may also assert that the cortex constitutes part of one of the paths, by which sensations may be brought into connections with movements. Since the brain makes possible movement when a sense organ is stimulated, certain parts of the cortex must receive axones of sensory neurones, others must send axones down to the muscles. Fibres have been traced to the cerebrum from sense organs, and from the cerebrum to the motor cells, and so to the muscles. The first problem is to determine these sensory and motor areas. One may picture the sense organs and muscles as projected upon the cortex. The areas that receive sensory excitations and send out motor impulses are known as the projection areas. Other areas have been shown to be connected with these, to have fibres leading to and from projection areas. These are known as association areas.

**The Motor Areas.** — The motor areas are most definitely determined. They are in the frontal lobe just in front of the central fissure, extending from near the fissure of Sylvius upward to the median fissure and over on to the median surface. The muscles of the head and face are represented

upon the lower portion, the areas for the arms, the legs, and the trunk are found in order as one proceeds upward. Since the descending fibres cross, the right half of the body is controlled from the left brain, and *vice versa.* The details can be made out with greater accuracy from the diagram than from any description. Some of the movements can be localized with great definiteness. The thumb has a separate area for the control of its movement, and the same may be said of other important organs and muscles. These areas have been determined, in part by a study of the paralysis that comes with disease and in part by noting the movements that result from stimulating different portions of the motor cortex in animals. Then, too, in the motor areas are certain peculiar cells, the giant pyramidal cells, whose axones can be traced down the brain stem and cord as the pyramidal tracts. Most important of all is the fact that it is possible to stimulate the motor cortex of a man whose skull has been opened for examination. In a very striking operation by Dr. Cushing, the skull was opened over a large area during primary anæsthesia, then the patient was permitted to return to consciousness and the cortex stimulated while he was in a condition to report on what happened. The results obtained in this way were sufficient to convince the world of science that the motor part of the cortex is restricted to the frontal lobe rather than extending backward across the central fissure, as was thought a few years before.

**The Sensory Areas.** — The sensory areas are widely distributed. The area for touch is found in the parietal lobe just behind the central fissure. The definite localization of parts of the body has not been determined as it has for movement. In fact, the opinion is still held in certain quarters that movement sensations alone — impressions

received from sense organs in muscle and tendon — have their seat in this region, while the skin senses proper are found elsewhere, but the upholders of this theory assign them to no definite place. Tracing paths and observation of injuries both coincide in giving this area to touch, whatever the final definition of that term may be. The auditory area has been located in the posterior portion of the temporal lobe, in the convolution adjoining the fissure of Sylvius, and probably extending over upon the wall of that fissure, the Island of Reil. Even more accurately determined is the region for vision. This is found primarily in the calcarine fissure on the occipital portion of the median surface of the hemispheres. It has been located, on the basis of examination of the brains of cases of cerebral blindness, by tracing fibres from the optic tracts to it, and by examination of the brains of individuals blind from birth or early childhood. Donaldson found, for example, that the brain of Laura Bridgman was quite undeveloped in this region. The partial crossing of the fibres between the eye and the brain has been very definitely made out. If the right occipital lobe has been injured, the patient is found to be blind in the right half of both retinas, while the left halves retain their vision. Each fovea, or central point of clearest vision, seems to be represented on both hemispheres. Apparently, too, the posterior part of this area for vision receives impressions from the lower parts of the retinas, while the anterior portion receives its fibres from the upper retinas. Smell, and particularly taste, are least well localized. This is primarily due to the fact that a patient may suffer from considerable defects in either sense without great inconvenience, and in consequence is less likely to complain and be carefully studied. Paths have been traced, however, from the olfactory nerve to the extreme

tip of the temporal lobe, the hippocamp. This region, too, is the analogue of the portion of the cerebrum that is well developed in the lower forms that show greater capacity for smell, so that all that we know points to it as the cortical seat of the olfactory sense. Taste is supposed to be somewhere in the same region, but the evidence is even less certain than for smell. Each of these areas can be better made out from the diagram (Fig. 32) than from verbal statement.

While the restricted areas described above are probably the more immediate sensory receiving stations in the cortex, it is not to be assumed that they are the only areas concerned. We have evidence that about both visual and auditory areas are regions that have a related function. Injuries in the temporal lobe near the primary auditory centre tend to decrease the efficiency of hearing. Lesions of the occipital lobe near the primary visual areas give rise to partial blindness or inability to interpret or perceive objects. These regions may be assumed to be active in connecting and elaborating the impressions received from the sense in question, rather than serving as the primary receiving centers.

**Association Areas.** — As will be seen from the diagrams, these projection areas, taken even in the wider sense of the last paragraph, include relatively small portions of the total area of the hemispheres. It was long a question what the functions of the other regions might be. Flechsig may be said to have found the answer. By his method of tracing the course of developing nerve tracts, he showed that masses of fibres led from the projection areas to the other regions of the brain, — that some were connected with few, some with many of these regions. He inferred from this that all of the cortex not included in the projection areas serves in

association. He even attempted to assign specific associatory functions to different areas. The posterior portions of the parietal and temporal lobes and parts of the occipital lobe he called the parieto-occipital association areas, and he assumed them to have the function of forming connections between the neighboring sense areas, and to be the seat of such associatory functions as those involved in the perception of space. The frontal lobe, so far as it is not included in the motor area, he makes the seat of the more complicated associations involved in reason and judgment. While the specific functions of different regions cannot be said to be matters of agreement, it is safe to hold that the general function of the silent areas is to make possible wide and greatly varied associations between the projection areas. There are formed the innumerable connections between different sensory processes and between sensory processes and movements so important for our daily life.

**Functions of the Frontal Lobes.** — Specific evidence of the dependence of associations upon the frontal lobes was obtained by Franz in experiments on cats and apes. When he taught his animals to make certain responses to given stimuli, and then removed part of the frontal lobes, the recently formed associations were destroyed, but an act that had been well learned was not disturbed by the operation. Animals that had been operated upon and had recovered, could learn new movements, and these were again destroyed by a second operation. It might be argued that the results noted were due, not to removal of a particular area of the brain, but to the shock or other general effects of the operation. To obviate this objection Franz removed other parts of the brain in control animals and found that the operation was without effect upon retention. He believes that his results have established the close connec-

tion of the frontal lobes with associations. Clinical observation in general supports the view that the frontal lobes are important association regions and the seat of complicated intellectual operations. When these are injured, the patient is usually incapable of the higher mental acts, is said to lose his character, to be reduced to idiocy or to a low mental state. On the other hand, considerable portions of the frontal lobe may be lost without any apparent effect upon the individual. Probably the two sets of facts are to be brought into harmony on the assumption that any part of the area may be used for associations; after associations have been formed in some one part and that part is removed, the knowledge is lost. When a portion is removed in which no connections have been made, no change in the animal can be noted.

**Aphasia.** — The coöperation of the various areas of the cerebrum in mental operations can be well illustrated by a study of the facts of aphasia, which we may undertake as a final review. This is one of the most familiar defects, and is also illuminating because speech stands in such close connection with all of the other mental operations. By aphasia is meant the loss of speech due to any lesion of the brain. Two forms of aphasia are ordinarily distinguished. One, motor aphasia, is characterized by inability to produce the vocal movements in a coördinated fashion, and has been connected since Broca's time with a lesion in the third frontal convolution, an area in front of the immediate motor centres for the muscles of the head and throat. The other is sensory aphasia, first reported by Wernicke in 1874. It is more closely connected with inability to hear, or to think of the word, a word deafness, and has been shown to be due to injury of the auditory centre and of the immediately contiguous areas of the temporal lobes.

**Partial Aphasias.** — In addition to the cases which show complete loss of function, together with loss of capacity to hear or to anticipate the pronunciation of words, one must recognize instances in which the patient can hear mentally, can reproduce words to himself, but cannot hear when words are spoken. On the other hand, there are patients who can recall the 'feeling' of words as they are spoken,

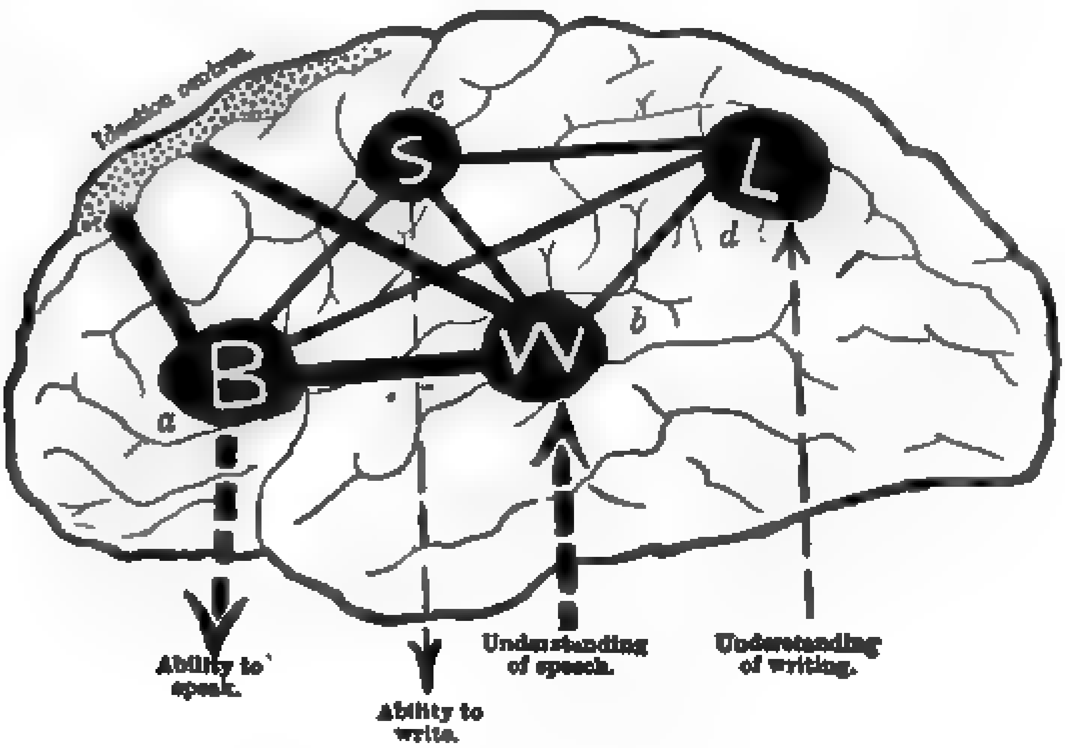



FIG. 33. — Diagram of speech areas. (From Bing, *op. cit.*)

can have all the antecedents of speech, but cannot speak. In these cases lesions have been found in the subcortical regions which affect the projection fibres on the path to the muscles. All the cortical processes go on as usual, but the connections with sense organ and with muscles are broken. Other distinctions can be made in sensory aphasia, in particular between injury of the primary receiving centre and the adjoining elaborating or memory areas. Thus, according to Adolph Meyer, when the first temporal gyre on the side next the island is injured, 'word-deafness' re-

sults. In case the lower portion of the gyre is injured, on the other hand, words are spoken hit or miss, what is called a 'word-salad' is frequent, memory for words seems disturbed but not destroyed. Still another element must be added to give a complete picture. Other than the auditory memories are necessary before the words can be understood in their completeness. This has been pictured by Wernicke and others as a process of connecting the word with a concept in a concept centre. The concept centre is probably too simple a way of disposing of the process, but it is necessary to connect the word or sound with a large number of other experiences before it is understood. With suitable reservations this may be interpreted to mean that the auditory impression makes many associations before it is transferred to the motor centre. If these connections are impaired, repetition of sounds heard is possible, but there is no understanding of what is heard, and no proper control of what is said.

Five operations may be thought of as necessary for speech: 1, the reception of the sound in the primary centre for hearing; 2, its elaboration in the association region about the primary centre; 3, more complete elaboration by reference to other than auditory experiences (transfer to the hypothetical concept centre); 4, arousal of the coördinated motor impulses in Broca's centre; 5, conduction of these to the separate motor centres, from which the impulses are sent down to the muscles. The functions of areas 4 and 5 are related in very much the same way that a higher coördinating region, such as the cerebellum, is related to the activity of a mere reflex centre. In the primary motor area, a single muscle or muscle group is made to contract by stimulation; in the Broca centre, a large number of sensory stimuli are coördinated

and distributed to each of the different motor centres to cause just the right amount of contraction in each muscle at just the right time, — to marshal the different component movements to produce a satisfactory total result. The disappearance of any of these centres, or of the connections

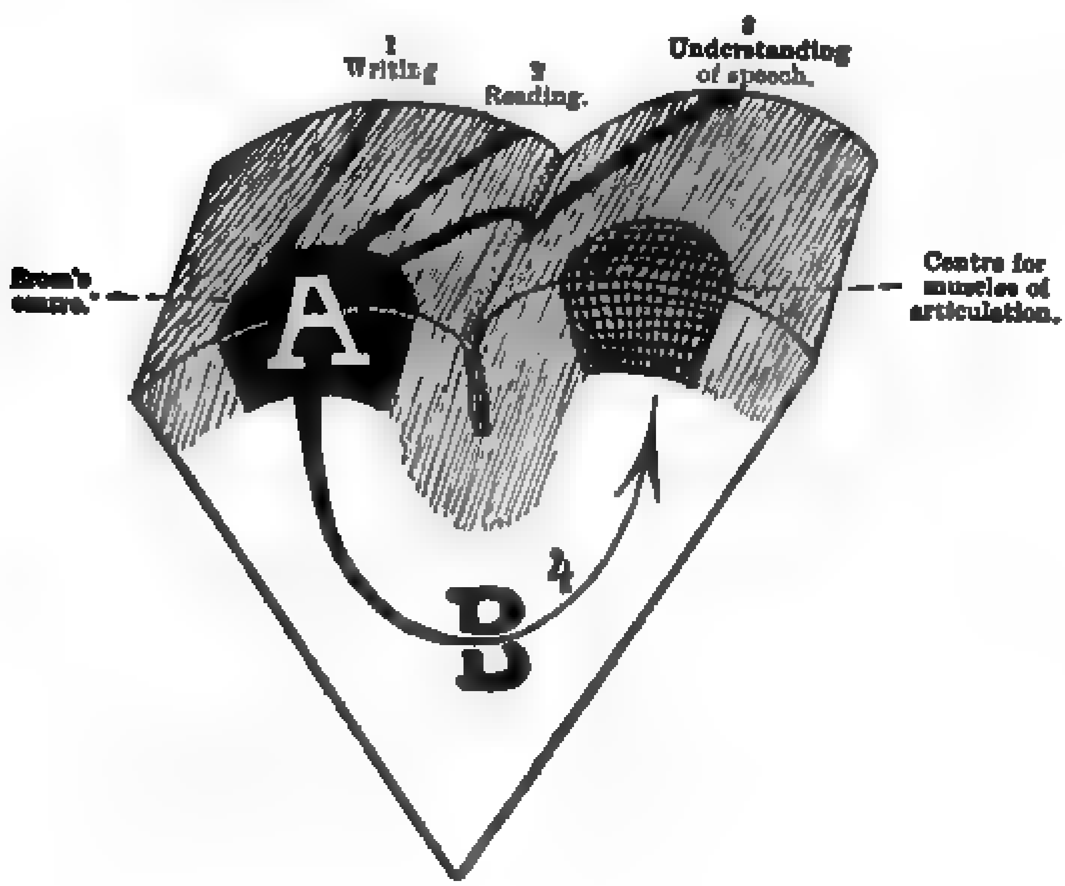



FIG. 34. — Showing connections broken in cortical and subcortical motor aphasia. In the former, 1, 2, and 3 are interrupted; in the latter only 4. (From Bing, *op. cit.*)

between them, produces aphasia, or in less serious cases, paraphasia.

Other centres that have been connected with the speech processes are the reading centre, which is localized on the lateral occipital lobe, and the writing centre. The reading centre has the same relation to the primary visual centre as has the auditory speech centre to the primary auditory centre. It may be imagined to be the region in which the

visual pictures of words are supplemented with memories and thereby understood. When the centre is injured, reading becomes impossible or inaccurate. The writing centre is not so generally accepted now as it was a decade ago. There have been a few cases of an inability to write with retention of ability to speak, but it is assumed that these were due to injury below the cortex or to paralysis of the arms due to lesions in the cortical area for the control of arm movements, rather than to the destruction of a single centre for the coördination of the specific movements involved in writing, similar to Broca's centre for speech. It should be said, in leaving the discussion of speech functions, that the cases are by no means so clear cut as one might wish. There is much contradiction and confusion in the reports of cases made which is only partially harmonized in such a schematism as that given above. Still this may be regarded as a simple picture of what takes place.

**The Left Cerebrum Dominant.** — It should be emphasized that, in right-handed individuals at least, the speech functions have their seat in one hemisphere mainly, the left. In cases of injury to the right brain in what corresponds to Broca's or Wernicke's centres, speech suffers little injury. Apparently this is only one phase of the general fact that in right-handed individuals the left hemisphere cares for the more important and delicate coördinations, while, with exceptions, the right hemisphere dominates in the left-handed individuals. If an injury be done to the right hemisphere in the third frontal convolution but the primary motor centres be not injured, the speech functions are not disturbed. Similarly, when the motor region in the left hemisphere is injured but the right is unaffected, it is found that the left hand is rendered incapable of delicate movements, although there is no sign

of paralysis and the coarser movements are unaffected. Liepmann found one case in which both hemispheres were normal, but where there was a lesion in the corpus callosum, the mass of fibres which connects one cortex with the other (Fig. 35). In this case, the right hand was normal,

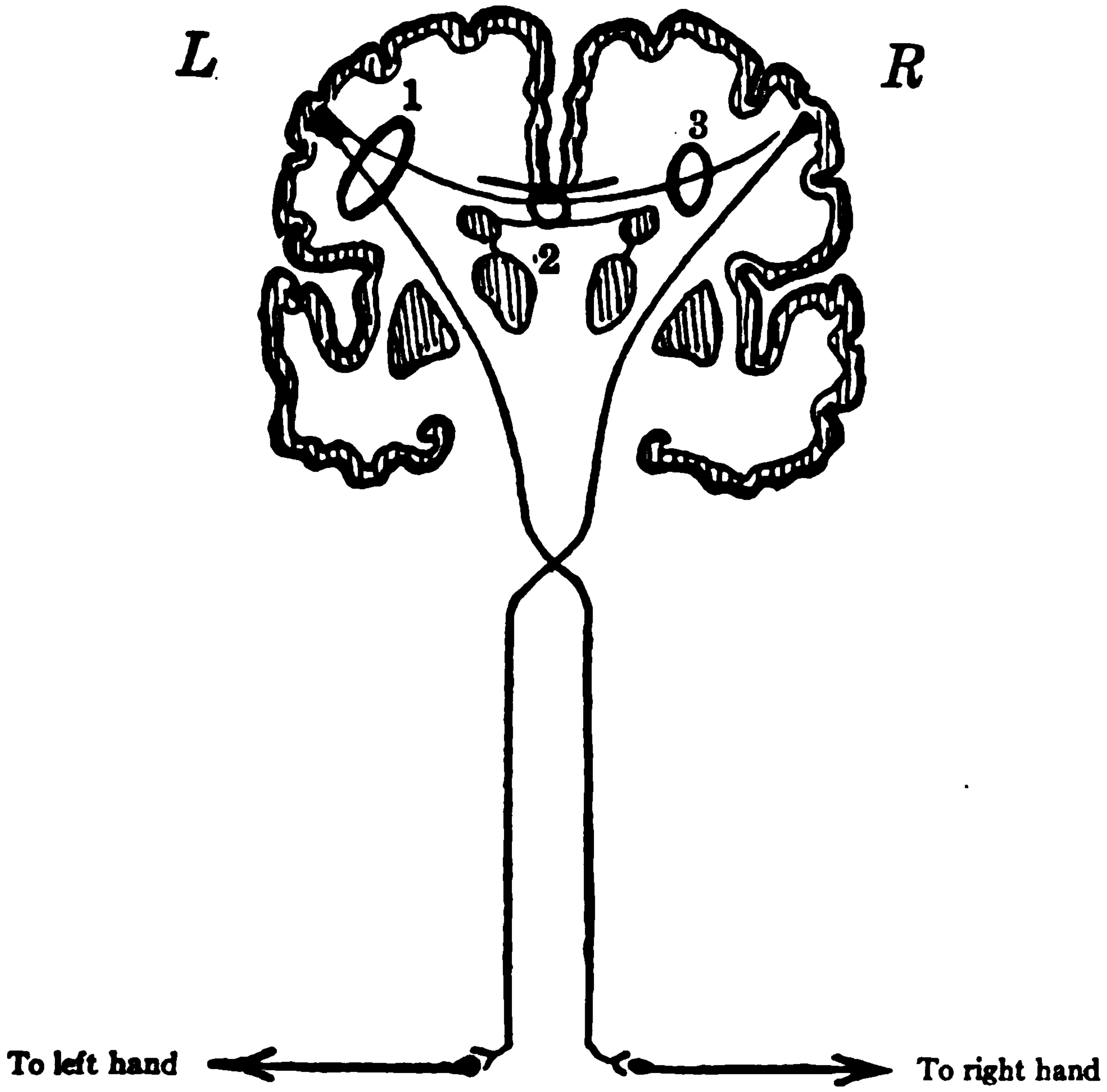



FIG. 35. — Showing the lesions that might break the connections between the left and right hemispheres and so produce apraxia of the left hand. If the lesion is at 1, the right hand will be paralyzed as well; if at 2 or 3 only apraxia of the left hand is caused. (From Bing, *op. cit.*)

the left what is called apraxic, — that is, delicate movements could not be carried through with accuracy. These cases indicate that the highest coördinations, whether in speech or in manual exercises, are accomplished in the left hemisphere. It has been suggested that right-handedness is really left-brainedness, and *vice versa*.

**Restitution of Function.** — Interesting, too, in this connection is the fact of restitution of function in cases of cerebral lesions. Not infrequently an aphasic will show marked improvement, sometimes almost complete recovery, with no betterment of the lesion. In surgical cases the patient will frequently show considerable paralysis immediately after part of the cortex has been removed, but with the passage of time his movements will become normal again. Various speculations have been indulged in to explain this phenomenon, such as that the function is taken over by the other hemisphere, that the paralysis is due to shock, and when that passes, the old structures regain their activities, or in general that some other part of the nervous system can take over the work. No one of these theories has received general acceptance, nor can any be said to be altogether satisfactory, but it is important in several connections to note that there is a considerable degree of flexibility in function exhibited by many of the nervous structures. Surgeons have joined part of the central end of a flexor nerve to the peripheral end of an injured extensor nerve and, when regeneration has taken place, the nerve and its central connections perform the new function without a hitch. In cases of destruction of paths through the cord, as in infantile paralysis, it is found that other paths will be substituted and the paralysis disappear in time, provided only that the muscle be kept from degenerating while new paths are being developed. Vicarious functioning, replacing of one structure by others, seems to be a fairly general law of nervous action, although much remains to be learned of the limits and details of the process.

**Résumé of Nervous Functions.** — In brief, then, we see that in the nervous system, the action of all parts depends

upon a transfer of sensory impulse to motor neurones, and the consequent excitation of muscular movements. There are three levels in the nervous system at which the transfer from sensory to motor organs may take place: 1, at the level of the simple reflex in the cord or brain stem; 2, in the higher coördination centres in the brain stem, the cerebellum, and the corpora quadrigemina; and 3, in the cortex. As one passes to the higher levels, the number of sensory impulses concerned in guiding movements becomes greater, and in consequence the movements become more accurately adjusted to the environment, to the circumstances of the moment. In the cortex, the association centres provide regions where all sense impressions may be brought into connection with each other and with retained impressions, and where all combine to control movements. Action is in the light of past as well as of present experience. In consequence, the highest forms of adaptation are possible. Aside, however, from the increasing complexity of interaction, the highest and the lowest forms of nervous action follow the same laws. The control of the path taken by the impulses through its structures may also be explained on the same general principles.

## The Synapse

**The Action of the Synapse.** — Perhaps the best notion of these principles is given by a theory elaborated by Professor Sherrington. This regards the course of an impression through the nervous system as determined by the ease or difficulty with which nerve processes may pass from one neurone or nerve element to another, the amount of resistance at the synapses. This has already been briefly mentioned in the preceding chapter. The great number of synapses that may be crossed can be seen in Figure 36,

which shows the large number of collaterals and end brushes of a single neurone from the cerebellum of a rat.

The final explanation of why one synapse should be more permeable than another, and why the same synapse should be more easily crossed at one time than at another, has been the subject of much discussion and is not completely agreed upon as yet. The earliest and simplest explanation grew out of the picture of the nervous system as


Fig. 36. — The numerous points of connection of a neurone from the cerebellum of a rat. (Cajal.)

a colony of individual cells, each like an amœba, which could control in some degree the extension and withdrawing of processes. Just as a group of amœbæ that happened to be in contact might send out pseudopods and touch each other at different times and places, so the neurones might on occasion send out or increase the length of the dendrites until they came into contact with the end brushes of the neighboring axones. It was further assumed that when physical contact was present between the neurones, a nervous impulse might pass, while at other times the path was blocked. Some authorities asserted that the

dendrites were shorter in animals killed by an anæsthetic than in others. The theory was used to explain sleep as due to a blocking of all the pathways to consciousness. Later consideration has led to the abandonment of the theory. It would make all action of the nervous system depend upon chance activities or arbitrary activities in the separate cells, rather than upon the way they were affected from without, or by other cells. Sleep might be satisfactorily explained, but on this theory it would never be possible to waken the individual until his neurones were ready to put out their dendrites again.

Sherrington is convinced from a careful study of the times required for the reflex movements under different conditions, that we must think of the nervous structure as continuous. A membrane at the synapse, probably analogous to the membrane of a cell, offers a resistance to the passage of the impulse. The degree of resistance is determined by the degree of permeability of the membrane. The neurones would always be in contact, the reflex path is always continuous, but the impulse is impeded at the point of contact between axone and dendrite.

If we may be satisfied with the theory, we still have to ask why one synapse should be more permeable than another. In the lower centres it may be assumed that the openness of certain synapses and the closed condition of others is inherited, that it either is present at birth or appears soon after as a result of the inherited predisposition. Few reflexes are perfect at first, — they improve for days or even weeks in the higher animals. At first the child does not accurately touch a point stimulated, although there is usually some indefinite waving of the arms. Many of the more complicated reflexes and instincts make their appearance late, although probably the development comes

in large part as a result of growth rather than of learning. The paths open at birth determine a relatively larger proportion of the total number of paths in the cord and midbrain than in the cortex, but probably form a large number of the total connections even in the adult cortex. The general lines of connection are pretty well laid down even there.

**Habit a Change in the Synapse.** — The connections that develop in the life of the individual as a result of learning are due to changes that take place in the character of the synapse. What this change is is not determined and cannot be, so long as we do not know what the nature of the opposition in the membrane may be. We do know that the more often two neurones are excited together or in immediate succession, the greater is the likelihood that the activity of one will extend to the other. All learning, whether in the formation of habits or in the connection of sensory impressions in sensory learning, is due to this reduced resistance. The laws that govern the reduction of resistance from use are known in some degree from the observations of the behavior of the organism, but our theory takes us only to the point where we may say that learning is due to some sort of reduction in the resistance offered by the synapse to the passage of the nervous impulse.

Our picture of the action of the cortex, as of the cord, is that all is determined by the openness of paths, by the synapses. The passage of the impulse from sense organ to muscle is, as has been emphasized repeatedly, the explanation of all function, whether in cord or in cerebrum. The difference between the two is that there are more open paths in the latter over which any impulse may pass and that for the most part these paths have been opened by use, by the earlier activities of the organism. It should also be emphasized that many different stimuli coöperate

in producing the activities that result from the action of the cortex, many more than act together in any of the lower centres or organs. The coöperation is made possible by the fact that many of the paths have common parts; in fact, that the motor part of the path is common to very many different acts. In the majority of cases the same muscles, and even the same groups of muscles, are used. The excitation of the motor path may be aroused by a number of sensory impressions, and the various impressions may be thought of as coöperating in the final action. What is even more important in this connection is that each sensory impression may be connected with several motor or intermediate neurones, and the action which results when the sensory impression is received must depend upon the openness of the various synapses, of paths leading to the possible motor organs that may be excited. Where very large numbers of stimuli are presenting themselves at every moment, there must be a large amount of coördination, of reciprocal influence, to determine which of the possible movements is actually made. The strongest impression and the one whose neurone has the most open synapses between it and the motor neurones will determine the action.

### Interactions of Impulses

**Facilitation of Impulses.** — In addition to this mere openness of paths and the greater strength of the impressions, coördination seems to imply mutual interaction between the neurones of one path and those of another. Sherrington and others have demonstrated two forms in which one path or series of neurones may act upon others. One, the more direct, is some process of making easier the path for one response by another set of neurones active at

the same time. This is very common. It may be illustrated very easily by the knee-jerk. You are familiar with the fact that if you strike sharply the tendon below the knee-cap when one leg is crossed over the other, the foot will give a kick. It has been shown that the kick will be much stronger if the hands are clenched at the time the blow is given. The clenching of itself would not produce the kick, but it prepares the way for, or facilitates, the response when the blow is given. This may be pictured as a preparatory reduction of the resistance of the synapse which makes the impulse pass more easily, and hence with greater intensity, when the suitable stimulus is applied.

**Inhibition of Impulses.** — More striking is the second form of interaction, inhibition. Certain paths when active prevent the action of others, or reduce their liability to response. Sherrington has demonstrated this phenomenon in the case of many reflexes, such, for example, as the general reduction of the strength of the reflexes of the cord when it is in connection with the cerebrum. After the cerebrum has been removed and the animal has recovered from the shock of the operation, all reflexes are exaggerated, a fact explained on the assumption that in the normal animal all lower reflexes are inhibited by the higher centres. More interesting for our immediate purpose is the fact, fully established by Sherrington and Hering, that the flexor and extensor centres in the cortex mutually inhibit each other. They removed the flexor muscles of a member, placed the animal in such a position that there was a tendency for flexion, — it was supported only by the extensor muscles, — and noted that the member was lowered when the flexor centre was stimulated. This they explained as an inhibition of the cortical centre of the extensor muscle from the flexor centre which reduced the tonus of the extensor, and

so permitted the member to be flexed. This was also demonstrated on the antagonistic eye-muscles. If the internal muscle of the eye were severed and the cortical centre for that muscle were stimulated, the eye would turn as it does upon stimulation of that centre when the muscle is intact. This mutual checking of antagonistic movements prevents any possibility of interference between groups of muscles in voluntary action. It makes it impossible that one group of muscles should pull against another. Inhibition is assumed by Sherrington to be due to the action of one set of neurones upon a synapse somewhere along the other path of discharge. The activity of that set of neurones, in some way as yet unknown, makes the membrane at the synapse much less permeable, and so prevents the discharge of the impulse across it.

These processes of facilitation and inhibition are quite as essential to the interaction of various stimuli in the cortex as in the lower centres. As will be seen from time to time in considering the mental processes, the most important and striking fact is the wide interaction of mental processes. It is seldom that an act or a thought is controlled by a single stimulus alone or even by the stimuli that are being received at the moment of action. The laws of facilitation and inhibition of one set of cortical activities by others that are going on simultaneously in other paths and in other areas, are needed if we are to obtain any accurate picture of cortical action. We shall have occasion to recur to these interactions in our explanations of mental processes.

### Consciousness

**Consciousness and Cortical Action.** — The relation of consciousness to the total action of the brain may be briefly mentioned. On the physical side, the action of the

nervous system may be thought of as the passage of chemical or electrical changes or processes through its various structures. These are present not at a single place but everywhere throughout the mass of neurones, — hundreds, if not thousands, of separate sensori-motor arcs are carrying impulses at the same time, — for the muscles not only are moved by nerve impulses when they move, but are also kept in slight or tonic contraction by the constant action of the neurones. But of all these activities, only relatively few, perhaps not more than one group at a time, are accompanied by clear consciousness. The others do their work without being noticed. If they contribute at all to consciousness, it is only by modifying the total mass in some slight degree. They are silent servants, or their addition is lost in the complex. The general rule is that consciousness attaches to activities which are performed for the first time, or which offer special difficulties. As movements are repeated, they gradually cease to attract attention, and usually by the time they can be carried out effectively, only the intention or the first beginnings of the act are conscious. There is no evidence, however, that the impulse follows any distinctively new path after it ceases to be conscious, that a voluntary act is first carried out by the cortex, for example, and then by the lower centres. It seems probable rather that consciousness drops away as the impulse crosses the synapses more easily. The paths followed are still the same when the action becomes easy, but we are not aware of the activity.

## The Autonomic System

**The Autonomic Nervous System.** — In addition to the central or cerebro-spinal nervous system which we have outlined above, the psychologist must also mention the

so-called autonomic nervous system. The autonomic system as a whole consists of a number of ganglia, whose function is to receive motor impulses from the cord and brain stem and distribute them to the viscera and glands that they excite. As compared with the central nervous system, the responses are very slow and are diffused throughout several organs, rather than being restricted to isolated groups of muscles. These ganglia lie on both sides of the spinal column in the central trunk and in the head and pelvic region are found near the organs they excite. They all receive fibres from the cranial nerves and spine. Fibres from the central nervous system make connections with the cell bodies of the autonomic system, and from these cell bodies non-medullated fibres extend to the organs which they innervate. They are distributors of motor impulses from the central nervous system.

Impulses from the autonomic system extend to all parts of the body. They cause contraction of the blood vessels, erection of the hairs in animals, changes in the size of the pupil, secretions of the glands, including the sweat glands, increased rate of the heart, movements of the walls of the intestines, the movements of excretion, etc. They are preeminent in the control of the fundamental bodily mechanisms. They affect consciousness most through their activity in emotions.

## The Ductless Glands and the Activity of the Nervous System

**The Ductless Glands.** — A series of organs and activities which need to be taken into account in connection with the activity of the nervous system and which depend upon the action of the autonomic system has been discovered relatively recently, the endocrine or ductless glands.

These glands secrete certain substances, known as hormones, directly into the blood. These hormones are essential to the proper functioning of the nervous system in particular and to the growth of many other parts. The list of glands which influence the nervous functions includes the thyroid and pituitary, the adrenal glands and certain parts of the sex glands. Possibly we should include also the thymus and pineal glands, although relatively little is known of their functions.

*The Thyroid Glands.* — The best known are the thyroid glands, relatively large masses in the front part of the throat (which, when abnormally enlarged, produce goitres). The secretions of the thyroid are essential to the mental life and to the proper growth of brain. A cretin, who is an individual with defective thyroid secretion, is of the mental level of a child of four or five, is short in stature, with general infantile contours of the body. That this is due altogether to lack of thyroid secretion is shown by the fact that feeding a developing child thyroid extract from a sheep induces a marked growth and increase in intelligence. A marked cretin at two years may be a normal child at three. The treatment must be begun early if it is to be effective, and the improvement will continue only so long as the treatment is kept up. Excess of thyroid secretion, on the other hand, induces an abnormal excitability, particularly of the emotions. Hyperthyroidism is marked by excessive pulse rate, by wasting, and muscular weakness, and by great irritability.

*The Pituitary Body.* — The pituitary body is a small protuberance on the under surface of the brain stem, just back of the optic chiasma, or crossing of the optic nerve. It is connected with the third ventricle by a hollow tube. Three parts can be distinguished, with secretions differing

in function. The anterior portion secretes a substance that promotes the growth of the body, particularly of the bones and connective tissues. Cases of giantism, associated with mental disturbances, have been traced to excessive secretions of this anterior lobe. The intermediate portion secretes a substance which increases the contraction of unstriped muscles, and another substance which probably passes directly into the ventricles of the brain and is essential to the proper functioning of the cortical tissues. Disturbances of this secretion result in a marked decrease in intelligence. The function of the posterior portion is not known.

*The Adrenal Glands.* — The adrenal glands are small glands near the kidneys, which have connections with the sympathetic nervous system. Excitation of the fibres innervating these glands induces a secretion directly into the blood that increases the heart rate, changes the composition of the blood, and causes the flow of glycogen from the liver. This adrenal secretion is an important factor in emotional excitement and we may postpone details until we consider them in that connection.

*Other Glands.* — It has been suggested that the pineal gland may have a similar function, possibly to inhibit the effects of the pituitary secretion, but the evidence is contradictory, and we must await further evidence before we can include it among the endocrine glands. The same may be said of the thymus.

The ductless glands as a whole are important because they secrete substances which are essential to the growth of the nervous system and to its proper functioning. For psychology, they have an interest since their action is involved in the action of the nervous system, and more particularly since in emotional reactions they influence the

responses of the vital organs directly, and indirectly they render the individual more susceptible to emotional reactions.

## Body and Mind

**The Relation of Body and Mind.** — Much of modern psychology since Descartes has dealt with the relation of the mental processes to the nervous processes which we have just been discussing. The problem originated from the fact that behavior may be studied in two ways, from without and from within. When one attempts to study man with the scalpel and the instruments of the physiologist, he deals always with the physical man, with nerve and nerve cell, with white matter and gray matter, but he never finds any trace of sensation, of the inner experience. On the other hand, when one studies the mental states and devotes oneself to what can be seen in one's own consciousness, alone, one never finds any immediate evidence of nerve cells. For the most part investigators have preferred one or the other of these approaches to the facts of mind, — few men have given due credit to both. Even where each attracts the interest of the same man, it is seldom that both are combined in a single statement, or completely harmonized. More frequently one is entirely subordinated and to all intents and purposes we are given an explanation that is either completely materialistic or altogether spiritualistic. Most writers compromise, and in subordinating one of the two series they make it almost incidental, without real force, a sort of ghost of mind or of body, as the case may be, which merely follows the activity of the other but has no influence upon it.

Very generally, at present, the two lines of approach are recognized and both of the resulting series of experiences

are accepted as real. The most troublesome problem is that of the relation between them. Two theories as to this relation may be recognized. One takes the natural attitude that the two series interact, as do series of physical events; that when a sense impression is received, it is transmitted to the brain by the paths we have indicated, and that in the brain it in some way gives rise to the incorporeal process we know as sensation or knowledge, in the same way that the vibration of a sounding body may give rise to vibrations in the air. Similarly, it is assumed on the other side that voluntary processes may produce changes in the nervous system and so in the physical universe, just as simply as do physical forces in other physical objects. This theory of the relation of body and mind is known as *interactionism.*

Another theory equally current at present is known as *psychophysical parallelism.* It is an expression of the conservatism of modern thinkers in refusing to assert any particular sort of relation between body and mind. The mental series is assumed to constitute one train of events which can be explained in terms of earlier mental events; the physical series, the changes in nervous elements, is made entirely distinct, and it is assumed that it can be completely explained in terms of the antecedent physiological processes. The relation between the two series either is left unexplained or it is said positively that there is no interaction between them. In recalling an event, for example, one would run through a series of ideas until the proper associate presented itself. On the physical side, the series in recall would depend upon the connections that had been established between neurones in different sensory areas of the cortex, and the action resulting from the recall would be due to the transfer of some nervous excitation

from a sensory area to the corresponding motor area. When it is asked, however, how it happens that the nervous processes are always accompanied by the mental states, one of two answers is made. The more extreme men assert that there is no present connection between the two series of events. Each runs its own course because of some of the antecedent events within itself, but nothing that happens in the other can influence it. The two are kept together because they go at the same rate, rather than because of any cross connection between them. Members of the other school are less dogmatic in the negative. They assert merely that they do not know the nature of the connection, not that there is no connection between the two series.

The evidence adduced by the upholders of each theory is largely negative. The negative considerations upon which parallelism is based are the fact that one never can appreciate both series at the same time, can see nothing pass, and that the two series of events are not at all comparable. One cannot think of a thought moving a stone, or, in Clifford's term, it seems absurd to assert that two cars are coupled by the bond of affection between guide and guard, and to speak of a thought making any change in nerve cells is on exactly that level. At times the argument is given a more formal turn in the assertion that to assume interaction is in violation of the doctrine of the conservation of energy. If the physical series is to be regarded as a closed system of energy, it can neither give off energy to the mental states as is required if sensations are to be caused, nor can it be changed by mental states, as would be necessary if human volitions were to exert an influence upon the nerve cells. In passing upon these objections, one must remember, however, that the doctrine of

conservation is itself only a principle that has been set up for convenience, and must be given up if it should cease to harmonize with facts, and also that it may be possible in the future to include the mental world in some wider system of relations in which the mental and the physical shall be brought together. The objection is more formal than real. We come back, then, to the original assertion that we cannot make a single observation that will include a mental event and the physical event which causes it or is caused by it, and in consequence cannot obtain even an approximate picture of how one is related to the other. There is not so much as a good analogy for the connection, and most explanations are analogies.

On the other hand, the interactionist insists with great firmness that mere failure to see what happens when two events succeed each other uniformly, does not prove that they do not stand in some active relation, even in causal relation to each other. It is very seldom, if ever, that one is actually aware that some force has passed from one physical object to another; one seldom knows anything of what has taken place between them. The ability to trace energy relations is the exception rather than the rule. In other words, the relation between the mental and the physical series of events is no more unknown than is any other active relation. There is therefore no more objection to regarding the psychophysical relation as causal than the relation between heating and expansion or any other simple physical relation. Physical cause is itself not understood, and, if one goes deep enough, is as much a mystery as the relation of mind and body. While one may grant all this very readily, it does not necessarily follow that to change from one side to the other too often and too quickly — to introduce mental elements into the physical series

and physical into the mental series — may not give rise to vagueness and uncertainty. As a matter of fact, while one may admit that there are causal interconnections between nervous system and mind, it is also true that many arguments become vague if the speaker jumps from one series to the other for an explanation. While we shall admit that mind and body undoubtedly interact, we shall endeavor as far as possible to keep the explanation of physical states in terms of antecedent physical states, and the explanation of mental states in terms of antecedent mental states, and assume as little interaction between the series as is possible. It is necessary to accept an effect of the sense organs and sensory neurones upon consciousness to understand the material of consciousness and an influence of voluntary processes on muscles if we are to understand action. Aside from these, however, clearness demands that all mixing of the two sets of explanations be avoided.

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# CHAPTER IV

## SENSATION

### General Remarks

We have seen from our discussion of the action of the nervous system that all nervous action starts in sensation and leads to movement. The first half of this assertion is to be our guiding principle in discussing the qualities of consciousness. All the materials of our knowledge are derived from sensation. We have just as many different sorts of consciousness as we have qualities of sensation, and consciousness persists apparently only so long as impressions are playing upon our sense organs. The old sensationalists, Hobbes and Locke, for example, insisted that there could be nothing in mind that had not previously been in sense. While we do not to-day accept the principle quite so literally as they did, yet it is easy to see that the fundamental qualities of mind are derived altogether from the external senses. One can imagine no color or sound that has not at some time been seen or heard; or, to put it more conservatively, one can call to mind no quality of any kind that has not at one time come through the senses. One cannot picture the color of an ultra-violet light, or think what it would be like if one were suddenly to develop a sense organ that might be affected by it, nor can one think how the magnet might affect one if some sense organ should be developed to respond to it. Memory, imagination, and reasoning are limited in the qualities that they make use of to the bare materials of sense. They may recombine

them, they may make use of the sense materials in new ways, but they can add no new qualities.

**Classification of Sensations.** — The qualities of sensation might conceivably depend either upon the nature of the stimulus or upon the nature of the receiving organ. The popular mind accepts the former, but most psychologists believe that they are determined by the character of the sense organ or the connected portions of the nervous system, by the nature of the sensory ends that are turned outward to the physical world. That the nature of the sensation does not depend altogether upon the stimulus is evident from the fact that different stimuli produce the same sensation when they affect the same sort of nerves. Thus we shall see that menthol, pressure, and heat or its lack all produce the sensation of cold when they act upon a cold spot on the skin. On the other hand, the same stimulus, an electric current, for example, produces a different sensation as it acts upon different kinds of sense organs: cold on a cold spot, light on the retina, etc. These facts and others seem to show fairly conclusively that the nature of the sensation is determined by the receiving organ, rather than by the stimulus that is applied; by the character of the receiving tissue that has been developed, rather than by the character of the outside world. If this be accepted provisionally, it furnishes a convenient means of classifying sensations. Could one but determine the different sorts of sense ends that come to the surface of the body or are imbedded in its substance, one would also have a complete list of the possible sensations. In practice one usually discriminates the sense quality first and later discovers the sense organ, but the classification nevertheless is assumed to be in terms of the sense organ. We may accept for the moment the general principle that the number of sense

qualities is determined by the number of sorts of sensory tissue that can be stimulated.

The classification of sensations still offers some difficulties, since the fundamental kinds of sense ends must be grouped in some way for convenience of treatment. In certain cases the similar nerves are combined in some one organ. Thus in the eye are thousands of nerve ends stimulated by the same physical forces, and giving rise to similar sensations. In the skin, on the other hand, four kinds of sense ends are scattered indifferently over the surface, and while we commonly speak of the skin as the sense organ of touch, there are really at least four different kinds of sensation received from the skin. Taste and smell offer an inconsistency of the opposite sort. The organs are distinct, but the stimuli are closely similar and the qualities of sensation are not discriminated by the popular mind, yet science and common sense follow the organ rather than the quality in making them distinct sense departments. One may say, then, that in classifying sense qualities, the organ provides the first means of grouping, and within the organ the subdivisions may be either in terms of the classes of stimuli, or of the qualities of sensation, or of both.

**Attributes of Sensation.** — When one attempts to enumerate all possible sorts of mental qualities or sensations, one sees very quickly that there are various kinds of differences that are not on exactly the same level. It is not possible to arrange all the different kinds of sensation from any organ in a single series, the members of which differ from each other in one respect only. Thus in the case of sound, we may distinguish differences of pitch and also differences of loudness. These vary independently. A high tone may be either loud or faint. These different ways in which sensations may vary are called the attributes of sen-

sation. How many attributes there are is by no means a matter of agreement. All agree that one must distinguish differences in *quality* from the differences in *intensity*. The quality may be said roughly to depend upon the specific character of the sense organ stimulated, while the intensity depends upon the degree to which the organ is stimulated. There are exceptions to both of these statements. In the case of light, for example, the strength of stimulus in part determines the organ stimulated. It has been proved that faint lights are seen by one set of organs, bright lights by another. In the eye, too, even with bright lights, variation in physical intensity is not distinguished from change in quality of excitation. The grays correspond to changes in strength of light, but the untrained observer puts them on the same level with change in color. Black, white, and gray are popularly regarded as colors. But in all other senses, the distinction in quality and intensity offers little difficulty, and these two attributes are recognized by practically all psychologists.

**Extent and Duration.** — More difficult it is, however, to dispose of some of the other attributes sometimes ascribed to sensations. Thus every object possesses extent and every event occupies time, has duration. Many authorities speak of extent and duration as attributes of sensation, as fundamental ways in which sensations may vary. In the simplest cases, these ways of varying seem immediate and unanalyzable, but in many more instances it is possible to show that the appreciation both of extent and of duration depends upon more complicated mental operations. They belong rather to the object than to the sensation as such. In consequence it is more convenient to treat them both under the head of perception, as a process of mental elaboration of sensations, rather than as an immediate characteristic of the elementary sensation. Very much the same state-

ment may be made of clearness and feeling tone, regarded by some authorities as attributes. It is at least a question whether feeling is not entirely independent of sensation and an equally primary mental state. Clearness is a change induced in sensations as a result of their connections in consciousness, not an attribute of sensations themselves. Whether we are to regard them as irreducible parts of sensations, or as independent elements, or as accidents of the ways of receiving the sensation, can be best discussed in a later chapter. For the present we may content ourselves with the statement that sensations vary in specific quality which depends primarily upon the nature of the receiving end organ, secondarily upon the character of the stimulus; and in intensity, which, in its turn, is dependent upon the amount of stimulation that affects the sense organ. Considering qualities alone, the sensations fall into certain series, marked by continuous change in some one respect. It is impossible, however, to find similar continuous changes from series to series. Thus colors vary in a continuous series of hues; sounds show a continuous series of pitches; but there is no gradation from sound to sight. Through each quality runs a series of intensities which is regularly graduated from zero to a maximum. We shall discuss first the qualities in their dependence upon the organ and the stimulus, then the intensities.

## VISION

**The Stimuli for Vision.** — We may begin with the most important, if one of the most complicated, of the senses, — *vision*. The physical stimuli for sight are vibrations in the ether ranging from some 400 to 800 $\mu\mu$[1] in length. Helmholtz

[1] $\mu\mu$ means thousandths of a thousandth of a millimetre. This is usually expressed as $\lambda$.

under favorable circumstances saw rays as long as 835 $\lambda$ and as short as 318 $\lambda$. For the average eye under normal conditions the values range from 760 $\lambda$ to 397 $\lambda$. Between these limits lies the visible spectrum from red to violet. We give names to different qualities, but it is somewhat difficult to say just where one color changes into another. The physical relations have little significance for the quality of the sensation, since the colors do not change in the same degree as the wave length and very few of the laws of color can be stated in terms of the wave lengths of light. We must turn from the physical to the physiological for an explanation of the phenomena that interest us. For this we must consider the essential features of the structure of the eye.

### *The Structure of the Eye*

**The Eye and its Appendages.** — The eye is a part of the brain that has come to the surface of the body in the course of its development, has increased the primary sensitiveness of nerve tissue to light by the development of new photochemical substances, and has gained a system of lenses, grown protective coats, and acquired a mounting that permits of ready turning in all directions. The eyes are mounted in deep conical sockets in the skull, where they are well protected. The eyeball is kept in its place in the socket by the capsule of Tenon, a pouch-shaped membrane that surrounds the posterior three fourths of the eye-ball. It contains synovial fluid which acts as a lubricant when the eye-ball turns. The muscles in its tissue also contract with the ocular muscles and prevent them from drawing the eye back into the socket. To prevent foreign particles from entering the socket, the front is closed by the conjunctiva, a membrane continuous with the inner lining of the eyelids

and the outer surface of the eyeball. The padding of fat, the conjunctiva, ~~and the~~ capsule of Tenon, hold the centre of the eye fairly well fixed, and at the same time permit it to turn easily about its centre.

**The Three Coats of the Eye.** — The eyeball is approximately a sphere, a little less than an inch in diameter (23–24 mm.). The spherical shape is given it by the outer or sclerotic coat, which is kept distended by the fluids within, submitted to constant pressure by the general circulation. This pressure amounts to about 25 mm. of mercury in the normal individual. The eyeball has three principal coats. The *sclerotic* is a tough protective coat of connective tissue. Inside the sclerotic is the *choroid* coat, made up mostly of blood vessels with some muscles and nerve fibres. Still farther within is the *retina*, the nervous structure and true sense organ.

Each of these coats shows modifications in some part. The sclerotic coat in the front of the eye has a shorter radius of curvature, is transparent, and bulges forward as a part of the lens system. Here it is called the *cornea*. It can be seen to protrude from the sclerotic if one will look across the eye of another. Back of the cornea is a chamber filled with a watery fluid. This is the anterior chamber, and the fluid, the *aqueous humor*. In this chamber is an extension of the choroid coat, the *iris*, which is not attached to the sclerotic or cornea, but extends across the anterior chamber in the aqueous humor. In its centre is a hole, the *pupil*. The iris gives the color that is regarded popularly as characteristic of the eye. In the dark types, black or brown, it is much pigmented; blue and gray eyes are less pigmented. The size of the pupil is determined by the relative degree of contraction of two muscles or sets of muscles: (1) a muscle with radial fibres, the dilator of the pupil, and

(2) the sphincter, a muscle with circular fibres. These are controlled reflexively by the degree of stimulation of the optic nerve. The course of the reflex in constriction was

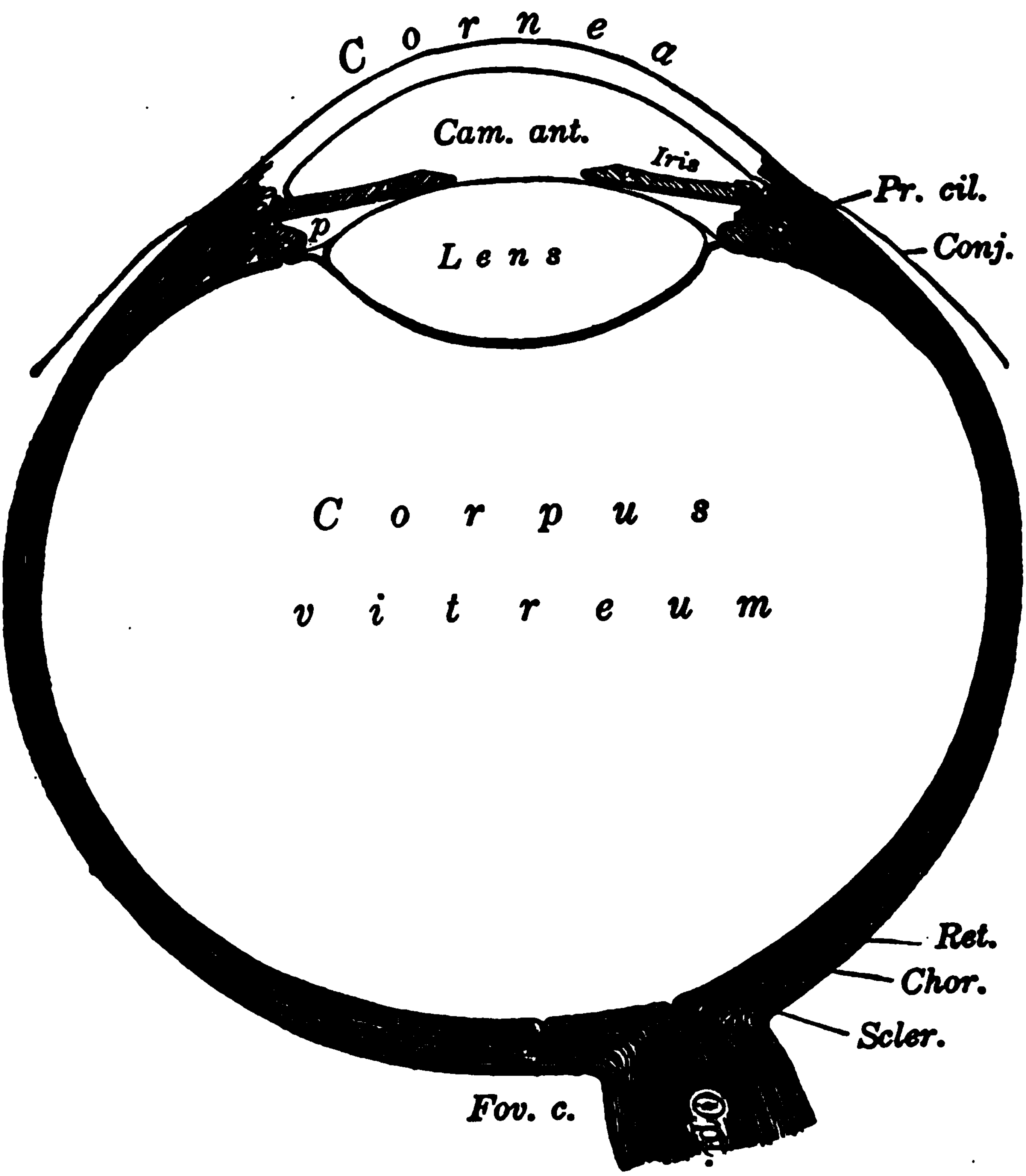


FIG. 37. — Section of the eye; *Scler.*, sclerotic coat; *Chor.*, choroid; *Ret.*, retina; *Opt.*, optic nerve; *Fov. c.*, fovea; *Pr. cil.*, the ciliary muscle or ciliary process; *Conj.*, conjunctiva; *Cam. ant.*, the anterior chamber; *corpus vitreum*, the vitreous humor that fills the main body of the eye. (From Angell's "Psychology.")

traced on page 56. Dilation involves a reflex through a long path down to the cord and back through the cervical sympathetic nerve and superior sympathetic ganglion to the

eye. The widespread course of the pupillary reflex makes it very important in the diagnosis of nervous diseases in general. It is affected by lesions in many different structures. In the normal individual, the constriction takes place promptly on increase of illumination, while dilation is relatively slow because of the long course through the sympathetic nerves. The function is in part protective by reducing strong lights, but also has somewhat the effect of

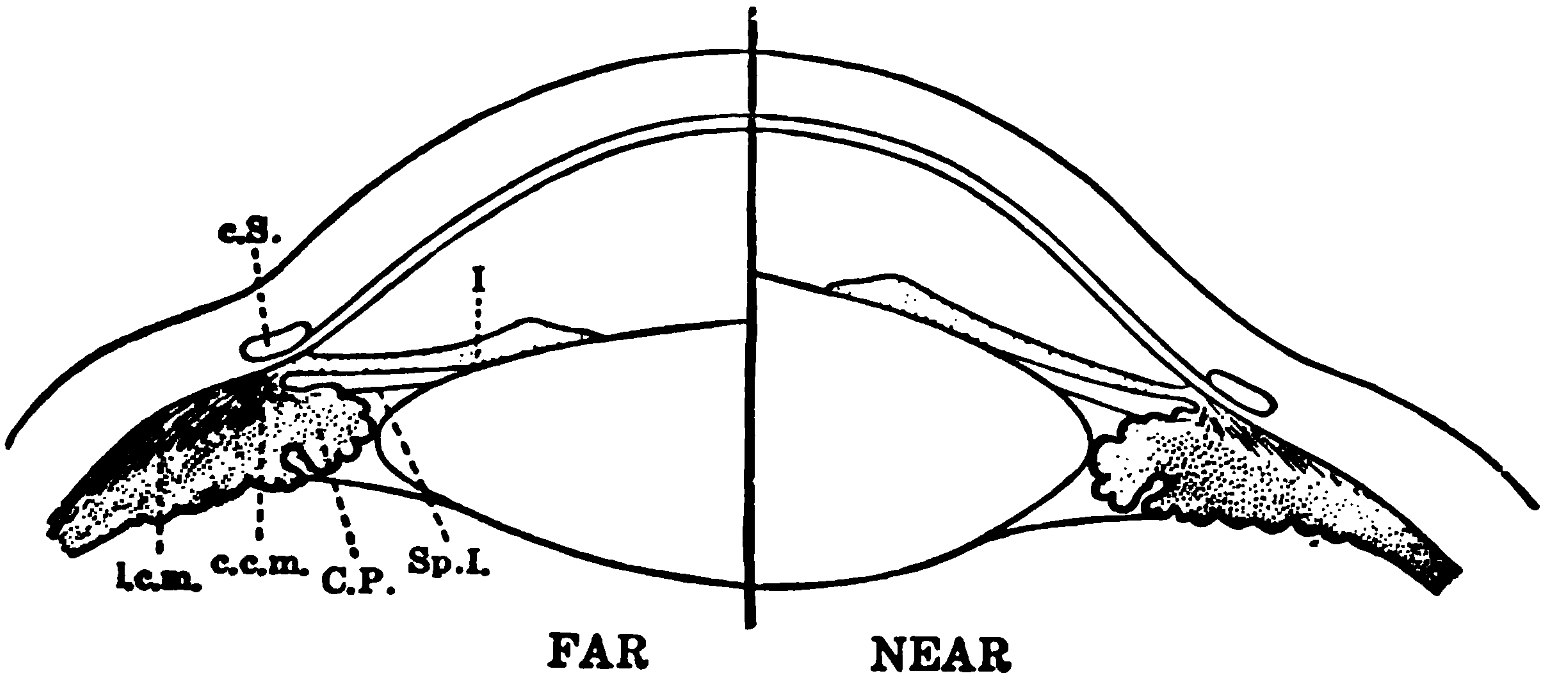


Fig. 38. — Change in lens and ciliary muscle in accommodation. Left shows accommodation for distant, right, for near objects. (From Foster's "Physiology.")

the diaphragm of a camera. It gives better definition because it "stops down" the pupil when the light is strong enough to permit and, when the light is faint, it admits more. Constriction of the pupil also accompanies accommodation to near objects.

**The Mechanism of Accommodation.** — Back of the iris and directly against it is the *lens*, the most important of the optical mechanisms. It consists of a large number of layers. The front surface of the lens has in youth a natural radius of curvature of 4.8 mm.; the posterior surface, of 4.6 mm. Ordinarily, however, it is held flattened by the strain of the suspensory ligament. This extends from the ciliary

processes on the ciliary muscle to the edge and the front and back surfaces of the lens. The lens with its attachments constitute the mechanism of accommodation. It makes possible the focussing upon objects at different distances. The active agent is the ciliary muscle. It is attached to the sclerotic coat near the angle formed by the increasing curvature of the cornea, and the fibres run back to lose themselves in the structure of the choroid coat. The suspensory ligament is attached to the side of the muscle instead of the end, as are the tendons of other muscles, so that the contraction of the muscle means relaxation of tension on the suspensory ligament rather than increase of tension. When the tension of the suspensory ligament is released, the lens resumes its normal shape, owing to its elasticity. As one grows older, the lens becomes less and less elastic, and accommodation practically disappears between 45 and 55 years. Back of the lens is the large main chamber of the eye, filled with the vitreous humor, so called because it has the consistency of molten glass. This fills the cavity between the retina and the lens.

**Dioptrics of the Eye.** — Regarded as an optical system, the function of the eye is to project an image of an object upon the retina. The important refracting surfaces are three, the front surface of the cornea and the front and back surfaces of the lens. The indices of refraction of the cornea, and of the aqueous and vitreous humors, are approximately identical, and each is approximately the same as that of water, — 1.337. The refractive index of the lens in practical effect is 1.437. The average radius of curvature of the cornea is 8 mm., of the front surface of the lens is 10 mm., and of the back surface is 6 mm. Calculation of the optical efficiency of the eye from these figures gives it a

value of from 60 to 66 diopters.[1] An eye with a length of axis of 22 mm. must have a strength of 66 diopters if the rays are to be focussed upon the retina. It is assumed that the normal eye has a strength of 64.50 D. The nodal point, the point through which all light rays may be assumed to pass, is 15.5 mm. from the retina and about 7.3 back of the cornea. One can think of the action of the lens most readily after the analogy of a pin-hole camera. Rays of light pass through a pin hole in a

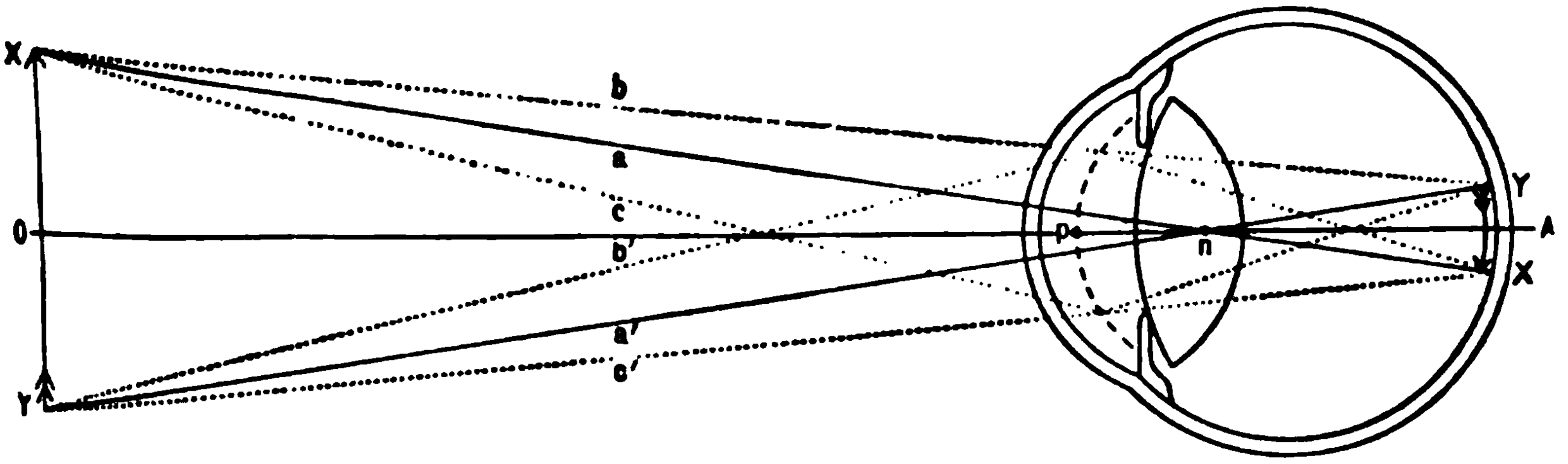


FIG. 39.—The formation of the retinal image. Shows refraction of three rays of light from *X* and *Y* that focusses them on the retina, and the inversion of the object. *P* is refracting surface of reduced eye. (From Foster's "Physiology.")

screen in a straight line from the object to the image. In the lens the rays also act as if they passed through a single point, the nodal point. In the average eye, the nodal point is 15.5 mm. in front of the retina and 7.3 mm. back of the cornea. The size of the retinal image cast by objects in the outside world and other relations of light rays are sufficiently accurately determined for most purposes if one assumes this position for the nodal point, and that the principal rays pass through it on the way to the retina.

[1] A diopter is defined as the strength of a lens that will bring parallel rays to a focus at a distance of one metre. The number of diopters of a lens is determined by dividing one metre by the length of its principal focus. A lens that brings parallel rays to a focus at 20 mm. has a strength of 50 diopters.

**The Structure of the Retina.** — The retina is practically a part of the central nervous system. It is a very thin coat of nerve tissue from .3 to .35 mm. in thickness. If we accept the neurone theory, the retina is composed of three layers of neurones, one with the modified sensory epithelium, the rods and cones, which receive the stimulation; one intermediate layer, the bipolar cells; and one whose cell bodies are the large ganglion cells nearest the vitreous humor.

The *rods* and *cones*, the structures sensitive to light, are directly in front of the layer of pigment cells and the choroid coat in the outermost part of the retina. The cones are relatively short and thick, from 4–6 $\mu$ ($\mu$ = .001 mm.) in diameter and 30–40 $\mu$ long. The rods are longer and more slender, 2–4 $\mu$ across and 40–60 $\mu$ long. They are crowded about as closely together as is possible, so that the distance from centre to centre of the elements is not much greater than the diameter of the single element. In both the rods and the cones can be distinguished an outer section and an inner section. Just at the base of the cones and a little distance away from the rods is a swelling that corresponds to the cell-body of the neurone. The axones of the rods and cones come into contact with the dendrites of the bipolar cells, and the axones of these in turn with the dendrites of the large ganglion cells. In the fovea it is said that a cone connects with a single bipolar cell and that in turn with only one ganglion cell. Thus the impulse from each cone in the fovea is kept separate all the way to the brain. In other portions single bipolar cells make connections with more than one rod or cone. In addition to these direct lines of connection with the central nervous system, there is a layer of cells between the rods and cones and the bipolar cells which serves to connect different rods and cones

horizontally. It is possible, even probable, that some of the spreading of impulses in contrast and irradiation takes place

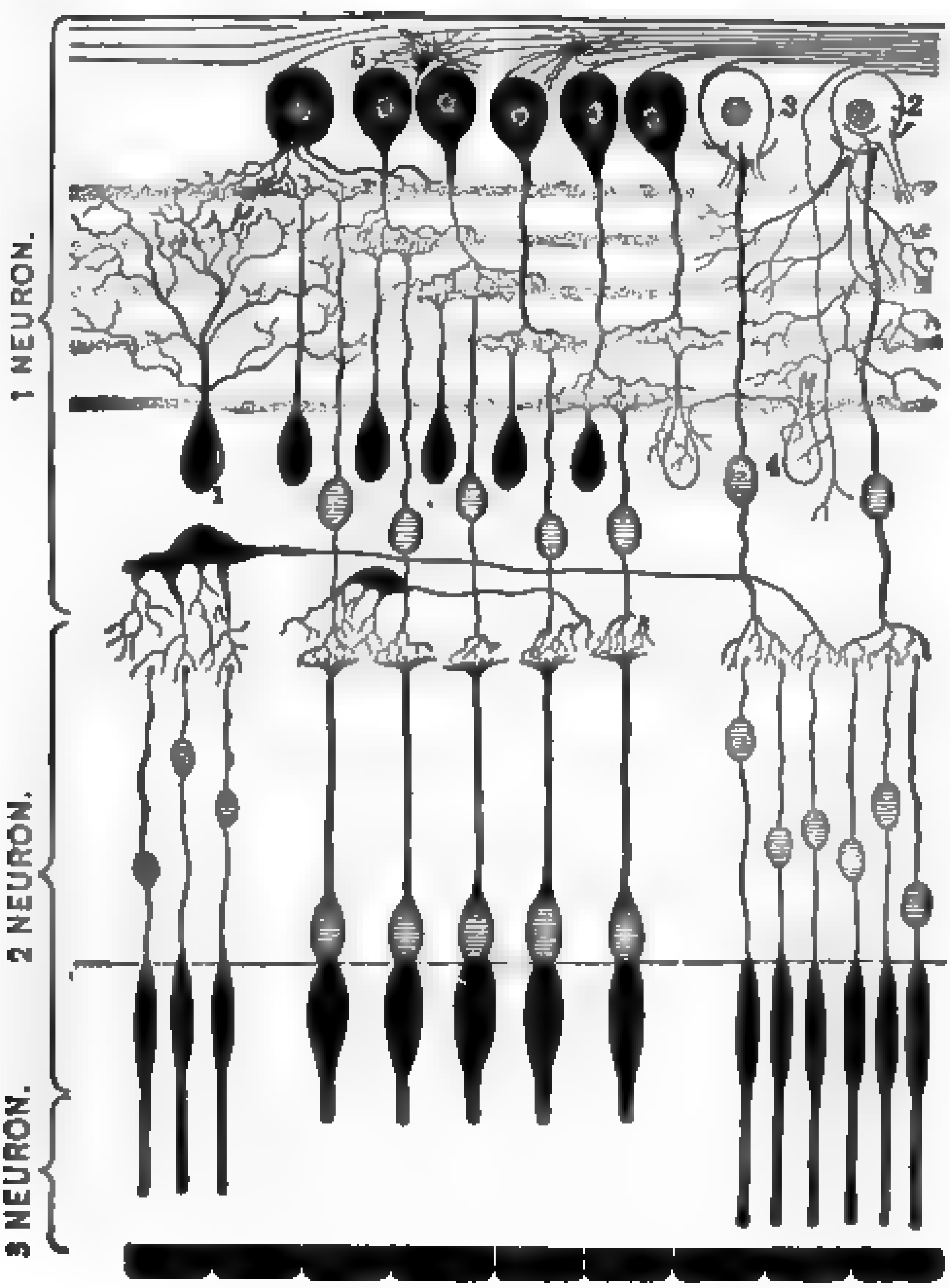


FIG. 40. — Section of the retina, showing the neurones. (After Cajal, from Howell's "Physiology.")

over these horizontal cells. In addition to these nerve cells, throughout the retina are found supporting cells of non-nervous tissue, the so-called Müller cells. In the innermost layer are fibres. the axones of the ganglion cells, which unite

to constitute the optic nerve and carry impulses to the cerebral nervous system.

**Fovea and Blind Spot.** — Certain parts of the retina show modifications from this general arrangement that make them of particular interest. One of these, the fovea, lies near the centre of the retina. It is the point of clearest vision, the point turned towards objects we desire to see distinctly. As its name implies, it is a pit or depression in the retina made by a drawing apart of the front coats of the

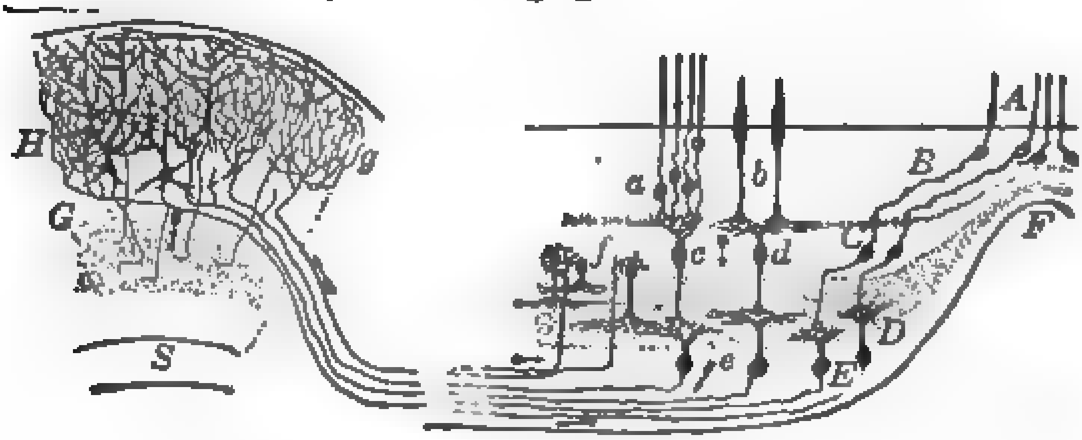


FIG. 41. — Section of the fovea. It may be seen that the axones of the cones extend toward the periphery to make connection with bipolar and ganglion cells. On the left may be seen the central cells to which the visual impulse is carried. *F*, fovea; *A*, *B*, *b*, cones; *a*, rods; *c*, *d*, bipolar cells; *D*, *E*, ganglion cells. This section is inverted as compared with Figs. 39, 40. (From Cajal.)

retina. This pit is due to the fact that axones which lead off from the cones go towards the periphery of the fovea, and the bipolar and ganglion cells with their axones and the blood vessels which supply the region are to one side of the cones rather than in front of them, – between them and the light, — as in other portions of the retina. The cones are here nearest the surface, and light need not pass through so much retinal tissue. In the fovea, too, are found only cones, and these are as long and slender as rods, so that the centres are only about 2–4 $\mu$ apart. In the neighborhood of the fovea the retina has a yellowish tinge. The fovea is 0.3–0.4 mm.; the rod-free area about 0.8 mm. in diameter. The

yellow spot is larger, 1–3 mm. in diameter. In psychological writings the fovea, point of clearest vision, and yellow spot are used almost interchangeably. This is only approximately accurate, as the dimensions of the yellow spot and fovea show. As one proceeds from the fovea, the rods become relatively more numerous, the cones less numerous, until at the periphery the cones are almost entirely lacking. Another region that deserves special mention is the blind spot, the area at which the optic nerve leaves the eye. This contains no rods or cones, but only the fibres, axones of the large ganglion cells, which unite to form the optic nerve. It is an area about 1.5 mm. (4°–6°) in diameter, about 5 mm. (15°) to the nasal side of the fovea.

**The Rods and Cones are the Organs of Vision.** — There is very good evidence that the rods and cones are the organs of vision. 1. Vision is absent where the rods and cones are lacking at the entrance of the optic nerve. 2. The shadows of the blood vessels in the outer coat of the retina may be seen under suitable conditions, and H. Müller has measured the distance of these blood vessels from the perceiving organs by a method of triangulation based on the apparent displacement of their shadows with known motion of the light outside. He found that the blood vessels were from 0.17–0.33 mm. from the perceiving coat, and measurements showed that the actual distance in the retina between blood

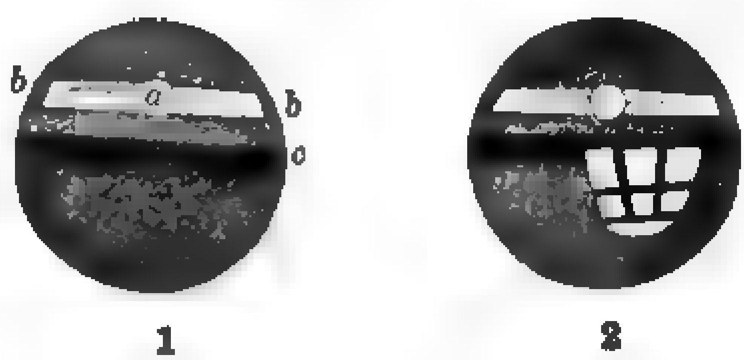


Fig. 42 — Optogram. *1* shows the normal appearance of the rabbit's retina; *2* shows the condition when the rabbit has been permitted to look at the window of the dark room and then is killed while still in the dark and the retina fixed as a photographic negative is fixed.

vessels and the layers of rods and cones was from 0.2 and 0.3 mm.

The problem as to what changes go on in the retina when it is stimulated, what actually makes one see, has aroused much discussion. Two changes can be seen to take place. One is a change in the color of the pigment in the rods. The retina of a frog killed in the light has a very light color. If, however, it be killed after being kept a long time in the dark, the rods have a delicate purple hue. Pictures may be taken with the retina of a rabbit. If the rabbit looks for a little time at the window of a dark room in which it is placed, then is killed and the retina fixed as one would fix a photographic plate, a picture of the window can be seen on the retina. Such an optogram is shown in Figure 42. It has also been demonstrated by a similar method that the cones contract in a bright light.

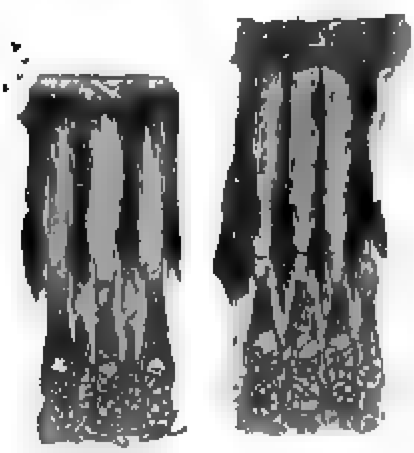

FIG 43 — Showing position of pigment cells. In the dark-adapted eye (right) they are outside of the outer layer of the rods and cones; in bright adapted eye (left) they are well down between the rods and cones. (From Siven and Wendt.)

Between the choroid and the retina is a layer of large pigment cells regarded by some authorities as belonging to the choroid, by others as an independent intermediate coat, and by still others as a part of the retina. These large hexagonal cells, like the black paint on the inside of a camera, insure the absorption of errant light rays. When the eye has been for a long time in the light, the cells are well down in the outer coat of the retina, and adhere to it. In the dark-adapted eye, on the other hand, they are well outside and come away from it freely when the choroid is stripped off. Of these changes only the bleaching of the visual purple has been given any meaning, and that

as we shall see, acts only as a sensitizer of the retina. (The positions may be compared in Figure 43.)

### *Sensations of Light*

**The Qualities of Vision.**—All theories of vision have been based upon a study of visual phenomena rather than on a study of the physiological processes. Knowledge of physiological processes develops from a study of the laws of sight rather than the other way round. The sensations from the eye may be divided into four different series. The first is the series of pure spectral colors, which range from red to violet. These are paralleled by the changes in wave length, and change in wave length may be regarded as the cause of change in hue. The second is the brightness or achromatic series. It corresponds to the changes in the intensity or amplitude of the vibration, provided the wave lengths are suitably mixed. The sensation series ranges from black to white through the grays which are intermediate. The third series accompanies change in the intensity of a single wave length and ranges from the most saturated or complete color to black at a slight intensity of stimulus, and again from the most saturated color to a whitish hue, at the maximum intensity. The fourth series corresponds to the mixture of a single wave length with grays of the same intensity. The sensations that result range from the pure color to a gray. The amount of the admixture determines what is called the degree of saturation of the color. The pure color is saturated, and the greater the amount of gray, the less the saturation. The last two variations are frequently mixed; saturation and brightness frequently change together.

**The Color Pyramid.** — The four series have been represented schematically by a double pyramid (Fig. 44). The

four primary colors red, yellow, green and blue are at the corners of the central square, with the intermediate pure spectral colors between. The oranges on the line between red and yellow, the yellow greens between yellow and green, and so on. At the bottom is black, and at the top white. The lines joining the square with the top and bottom represent the tints and shades. When a red wave is increased in intensity above the point of saturation, pink, a tint, is seen; when diminished, brown, a shade, is perceived. The central line that connects black with white represents the series of grays. The various degrees of saturation are represented by lines on the base of the pyramid from the outer square, where lie the spectral colors, to the centre that represents the neutral gray. The color tones are more and more mixed with the neutral tint from the circumference inward until color altogether disappears in the centre. The fact that the color may be mixed with a gray of greater or less brightness and so reduced in saturation and changed in brightness at the same time, can be represented on the pyramid by lines from the base of our double pyramid to a point on the central line at any distance above or below the base. That the spectral colors are of different brightnesses has been represented by tilting the square base more or less, making the yellow corner higher than the

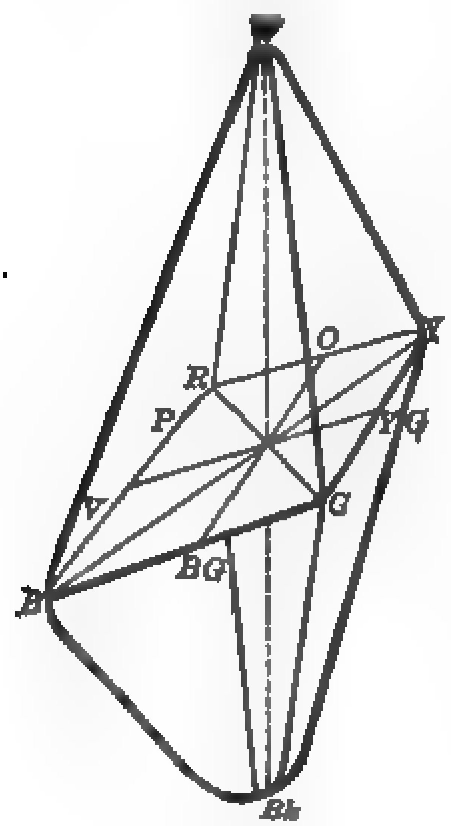


FIG. 44.—Color Pyramid. (From Titchener's "Textbook of Psychology.")

blue. We shall treat each of these series of sensations separately as far as possible.

**Hue.** — We may begin with the colors of the spectrum. The spectrum is a continuous series of colors which shade one into the other with no breaks readily observed at the first glance. The one fact that has been emphasized by direct observation is that there are certain turning points in the apparently continuous series, points where one quality gradually disappears and another gradually begins to show itself. Thus, at the long-wave end, red predominates. As one moves the eye toward the short-wave end, red gradually becomes less and less pronounced until it is finally lost at 588 λ in the yellow, which has also been present in some degree from the beginning. When red disappears, green begins to appear and gradually increases. In the meantime yellow gradually diminishes in amount until it disappears at 526 λ and blue takes its place. Still another of these critical points occurs farther on at 484 λ, where the green disappears and is replaced by the red of the violet colors at the short-wave end.

**Color Mixture.** — The terms we have used imply that there are in the spectrum relatively few simple colors and that any two of these may be distinguished in the intermediate colors. All theories, ancient and modern, have been an attempt to discover just what these simple colors are, and to determine how they combine to produce the other colors. The first experimental indication of the fact that most colors are compound is obtained from color mixing. Colors may be mixed, either by having two different wave lengths of light fall upon the same spot of the retina at the same time, or, more conveniently, by rotating disks of the colors to be mixed so rapidly that one color appears before the effect of the other has disappeared. Both

methods give approximately the same results. The first law of color mixture is that two spectral colors when mixed give a color that lies between them in the spectrum. When the colors lie near together, the resulting color approaches saturation; the farther apart the two colors in the spectrum, the less is the saturation. Not only may we obtain spectral colors from the mixture of spectral colors, but, if different proportions of the extreme ends of the spectrum be mixed, colors are produced that correspond to no single wave length but are nevertheless true color tones of a high degree of saturation. These are the purples, mauves, and other similar qualities. Since they grade from red to violet, they may be regarded as filling the gap between the two ends of the spectrum. For sensation, then, the series of colors can best be pictured as a closed figure rather than as a straight line. The direct psychological evidence for this is that the two ends of the spectrum are more alike than are points nearer together. Violet has a greater similarity to red than has any spectral color beyond pure yellow, and the two ends of the spectrum may be joined by suitable mixtures of the extreme colors.

**The Primary Colors.** — All agree that the colors we see in the spectrum are due to the stimulation of relatively few processes in the retina. These colors which may be regarded as pure are called primary. What the simple processes are has been in dispute between two opposing groups of theories. One, represented by Young, Helmholtz, and their followers, uses the facts of color mixing as a criterion and so chooses three, the smallest number of colors that will give all of the other hues by mixing, and of the possible groups of threes, selects those that produce all of the others in the maximum of saturation. These are red of the end of the spectrum, green of approximately

526 λ, and blue or violet 475–430 λ. For these three-color theories, yellow is a compound of green and red. A theory that would make four primary colors the basis for the composition of the spectrum was suggested first by Leonardo da Vinci and has received support on the more physiological side by Hering. Hering's four colors also, when combined, give the spectrum and in even greater saturation than the three colors. He chooses a red which is a combination of a little blue with the spectral red, a yellow of 575 λ while the green is of 495 λ and blue of 471 λ. The spectral values for red and green in particular are relatively uncertain since they vary somewhat for different observers. But it will be noticed that the green is of a considerably shorter wave length for Hering than for Helmholtz. Helmholtz' green would be a yellow green for Hering, while his red would be a yellowish red. Hering states that the reason that Helmholtz asserted that red and green combine to give yellow was because Helmholtz chose both red and green with a yellowish hue, and when mixed red and green cancel, leaving the yellow predominant.

That the spectral colors are derived from a relatively small number of simple colors seems demonstrated, first, by the fact that colors similar to those produced on the retina by single wave lengths of light can also be excited by stimulating the retina with two different wave lengths suitably chosen; and secondly by the fact that the purples, which physically are always mixed colors, seem just as true colors as those produced by a single wave length. Irrespective of the number and character of the simple colors, it is assumed by all theories that there are separate substances or processes in the retina for each of the primary colors, and that these simple structures or processes combine their effects in some way in the production of composite colors.

It is further asserted that other ~~than the~~ primary colors aroused by single wave lengths are really mixed colors, physiologically. Thus blue-green in the spectrum produced by a single wave length is physiologically compound, due to the simultaneous action of the blue and the green organ or process.

**The Nature of White Light.** — A second law of color mixing is that certain spectral colors when mixed in the right proportions produce, not an intermediate color, but a colorless sensation, a gray, whose shade depends upon the amplitude of the light waves. Colors which cancel each other in this way are called complementary colors. This brings us to a consideration of the physical nature of white light with its darker tones of gray and black. There are no single wave lengths that give rise to these brightnesses. They are produced only when certain properly chosen combinations of wave lengths affect the retina. In the sunlight all the colors of the spectrum are present, but the result for sensation is a somewhat yellowish white, owing to dominance of the yellow lights.

**Complementary Colors.** — To produce white, the simple wave lengths must be present in the right number and proportion. Both theories assume that white or gray light is produced when all of their primary colors are present in the proper balance. For Helmholtz all must excite the retina at the same time, while Hering asserts that white is seen whenever both components of either of his complementary pairs of simple colors are active in the same degree — when red combines with green or yellow with blue — and that they are all present in the spectrum in almost the proper balance to neutralize each other. This explains the fact mentioned in connection with the first law, that spectral colors when mixed do not give a saturated color and

that the farther apart they are in the spectrum the less saturated they become. Colors farther apart are more nearly complementary, and so more white is present in the compound. The list of wave lengths of colors that are complementary is given in Table I. It will be seen that no simple statement can be made of the relation of the wave lengths of complementary colors. Each must be determined for itself. As a result of the facts stated in

TABLE I. — TABLE OF COMPLEMENTARY COLORS FOR TWO OBSERVERS

| Observer von Kries | | Observer von Frey | |
|---|---|---|---|
| Long Light Wave in $\mu\mu$ | Complementary Short Wave | Long Light Wave in $\mu\mu$ | Complementary Short Light Wave |
| 656.2 | 492.4 | 656.2 | 485.2 |
| 626 | 492.2 | 626 | 484.6 |
| 612.3 | 489.6 | 612.3 | 483.6 |
| 599.5 | 487.8 | 599.5 | 481.8 |
| 587.6 | 484.7 | 587.6 | 478.9 |
| 579.7 | 478.7 | 586.7 | 478.7 |
| 577.6 | 473.9 | 577.7 | 473.9 |
| 575.5 | 469.3 | 572.8 | 469.3 |
| 572.9 | 464.8 | 570.7 | 464.8 |
| 571.1 | 460.4 | 569.0 | 460.4 |
| 570.4 | 440.4 | 566.3 | 440.4 |
| 570.1 | 429.5 | 566.4 | 429.5 |

this law it may be asserted that each color has a complement, that all colors go in pairs, although the colors in the middle of the spectrum have non-spectral colors as their complements. In terms of the four-color theory each primary color has a complement — green is the complement of red, blue of yellow. As each combination of two colors is made up of two simple colors, there is always a second combination of two colors, each complementary to one member of the first pair, which when mixed give gray.

**Color Blindness.** — The phenomena of color blindness offer much aid to an understanding of color vision. Some

three to five per cent of men and a much smaller percentage of women are found by tests to be unable to distinguish red and green. To them certain reds and greens look exactly alike. When the proper changes in brightness are made, red and green papers look gray and all three may be confused. The fact of confusion has been noted for a long time. The chemist Dalton furnished one of the first instances recorded, and for a long time the defect was known as Daltonism. It is only recently that fairly general agreement as to the explanation has been reached. Young and Helmholtz and their followers were of the opinion that one might be blind to only one color, one might be red-blind or green-blind, or both. Studies by Von Kries and others who were originally pupils of Helmholtz convinced them, however, that on the whole Hering was right in his statement that when one of a pair of complementary colors could not be seen, the other was also wanting. In brief, the red-blind individual is also green-blind and sees both colors as grays. Still rarer are the cases in which the sufferer sees no colors, but only grays. One other case is rarest of all in which the patient is blue-yellow blind, and can see red and green, but not blue or yellow.

**Peripheral Vision.** — Closely related to the phenomena of color blindness is the vision on the peripheral retina of the normal eye. It may be said that every eye has in it a red-green blind area and a totally color blind area. If one will look at any color out of the side of the eye, it will be seen that the colors undergo a marked change. One can see the full range of colors only for twenty or thirty degrees from the fovea; the distance varies with the individual and with the diagonal that is used. Beyond that one can see no reds or greens, but for ten degrees or so farther blues and yellows alone. Beyond that grays only are perceived. The field of

vision for colors and for grays extends much farther on the temporal side and below than on the nasal side and above. Different experiments will not ordinarily show that members of the same pair of colors vanish sharply at the same point, since the point of disappearance depends upon the size of the colored surface, upon the saturation and tone of the color, upon the brightness of the color, and upon its contrast with the background, and care must be taken to obtain standard stimuli and conditions. When all the colors used have the same values in these respects, the colors vanish by pairs as indicated above.

These facts of color blindness and of peripheral vision indicate that the four primary colors are closely joined in pairs. A study of the colors that remain to the color blind and of the way colors vanish on the periphery of the eye is, then, an important aid in determining which are the primary colors. That there are four colors rather than three becomes evident from the fact that first red and green disappear and then yellow and blue.

**Negative After-Images.** — Two other subordinate phenomena emphasize the opposition between these pairs of colors. These are the negative after-image and contrast. One may obtain a negative after-image if one looks for several seconds at any color and then for a couple of seconds at a neutral surface. The negative after-image is a fainter patch of the complementary color which gradually makes its appearance upon the neutral surface and remains for several seconds. The length of time that it lasts depends upon the intensity of the original color, upon its duration, and the extent of the surface stimulated, and upon the degree of fatigue of the eye. If two primary colors are present in the inducing stimulus, the complement of each will be present in the after-image. Thus purple

gives a yellow-green after-image, and orange, a greenish-blue after-image. The complete explanation of this phenomenon can best be discussed in connection with the theories of color. We may be content here to regard it as another indication of the fact that complementary colors stand in a very close relation to each other.

**Contrast.** — The laws of contrast may be stated in terms very similar to those used for the after-image, different from it only in that one relation is spatial, the other temporal. One has been called successive, the other simultaneous contrast or induction. Wherever a color stimulates the retina, a complementary color is induced in the surrounding area. The brightness of the induced color and the size of the halo depend, again, upon the brightness of the color, its size, and upon the similarity in brightness between the color and its background. Contrast colors can be seen most easily if a colored light and a white light are admitted to a dark room and a rod casts a gray shadow on the colored surface. The shadow will appear in the complement of the color. Thus shadows on the grass are purple, those on the snow in yellow sunshine are blue, etc. A gray strip of paper on a colored surface also takes on a color complementary to the paper, but it is not so easily seen by the beginner. If one will cover the entire surface with tissue paper, the contrast color comes out clearly. In general, the rule holds that the less definite the contour between the inducing and the induced color, the more definite the contrast. The individual has become so accustomed to seeing contrast colors that he forms the habit of allowing for them and sees the objects in the colors that they would have, were they alone. He has learned that a gray strip of paper looks red on a green background and sees the gray that is known to be the real color of the paper in spite of its appearance. The tissue

paper makes it difficult to be sure that the gray strip is really a separate object on a colored surface, the habitual interpretation is not applied, and the contrast color that is really present on the retina is seen.

**Summary of Facts of the Chromatic Series.** — Of the pure spectral colors we may assert that all are combined from four primary colors, — red, green, yellow, and blue — and that these four colors are paired in most of their activities, red with green, and yellow with blue. Each when mixed with its complement gives gray. In color blindness and on the peripheral retina, red and green, yellow and blue, disappear together. When one of these colors stimulates the retina, its complement appears in the after-image. The complement also irradiates from its surface, giving the contrast color.

**The Achromatic Series.** — The achromatic series is less rich in sense qualities. It contains only the series of grays, ranging from black to white. There are no breaks or turns in it as in the color series. Like the color series it shows the phenomena of positive and negative after-images, of contrast, and of mixture, in so far as two grays when mixed give an intermediate shade. The physical conditions of seeing the achromatic series are implied in the name. Whenever colors are eliminated in any way, the gray alone is seen. There are five conditions under which this elimination may be brought about: by combining colors in pairs of complements, discussed on page 114; by reducing the intensity of the light; by reducing the size of the area affected; by reducing the time of stimulation; by stimulating with any wave lengths the periphery of the retina or a totally color blind retina. These facts indicate that there is a different organ for brightness and that this organ is stimulated in isolation whenever the color processes

cancel; when the light is too faint to arouse the color organs, but will still stimulate the brightness organ; when the duration is too short to arouse the color processes; and where the color organs are absent as on the periphery and in the color blind eye.

**The Duplicity Theory.** — Within the last generation, evidence has accumulated that there are two organs of brightness instead of one. One of these is in the cones; it senses the brightnesses of moderate intensity. The other is in the rods, is more sensitive, and appreciates the brightnesses in faint lights. It is possible to compare the effects of stimulation of the two organs, from the fact that the fovea has cones alone, and also because of the greater sensitiveness of the rods. Three facts may be adduced as evidence of the difference in function of rods and cones. First the rods are more sensitive to faint lights than are the cones. Second, the rods respond to all wave lengths by brightness alone, while the cones respond to different wave lengths with different colors. Third, the rods are more sensitive to the short wave lengths, the cones to the long wave lengths. We shall consider each of these phenomena separately.

**Adaptation in Faint Light Vision.** — The most striking phenomenon of adaptation is the great increase in sensitivity of the retina after a period in the dark. After an hour in the dark the eye is about 100 times as sensitive as it is in ordinary day light indoors and from 100,000 to 150,000 times as sensitive as it would be after a long period in the bright sunlight. Adaptation continues for as much as sixteen hours, but is most rapid in the first few minutes and is relatively slight after the first hour. It is probably due in very small part to the expansion of the pupil, but for the greater part to the visual purple which regenerates

after a time in the dark, and by some chemical action increases the sensitivity of the chemical substances in the rods. The fovea in an area of about two degrees in diameter shows little adaptation to the dark. It undergoes a quick adaptation for two or three minutes and then remains constant. In the dark-adapted eye the most sensitive point on the periphery according to Nagel may be 1000 times as sensitive as the fovea. In day light adaptation the fovea is 20–40 times as sensitive as the periphery. It is for this reason that one can see a faint star better if one does not look at it directly but sees it out of the corner of the eye. Adaptation is almost entirely restricted to the rods.

**Disappearance of Color with Reduction of Illumination.** — The most noticeable difference between the spectrum as seen at the intensity of ordinary day light and in the faint light of a dark room is that the colors are altogether lacking at the low intensities and the spectrum appears as a band of gray light. As the intensity is diminished, the colors disappear in different orders. The reds and violets vanish first and the orange is the last to go. Mixed colors change their hue with the reduction of the light. Scarlet becomes orange, orange, more yellow, and blue-green shifts towards blue. With the exception of extreme red, the colors are seen as brightnesses after they disappear as color. Blue has the longest of these colorless intervals. This so-called 'photo-chromatic interval' is not present at the fovea. There the colors are not seen as grays after they cease to stimulate the retina as colors. This leads us to believe that the colors are seen by the cones alone; brightnesses of low intensities are seen by the rods. Where the rods are lacking there is no gray that persists after the colors cease to be seen.

**The Purkinje Phenomenor** change in brightness of differer diminution of intensity is quit blue seem of equal brightness ii

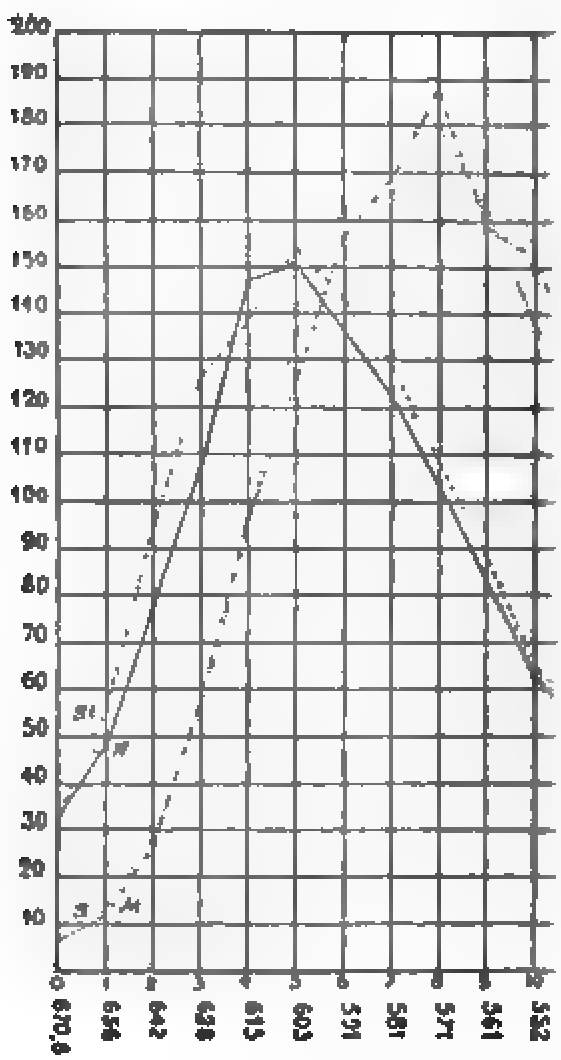

FIG. 45. — Chart showing relative brigh light for two protanopes, *S* and *M*, and f ...anopes, *St* and *N*. (From von Kries.)

will be much brighter in reduced illumination. The short wave lengths have a much greater effect upon the rods which are active in the faint light. In this they stand to the cones much as the photographic plate, which registers the shorter waves but not the red, to the eye as a whole. In day light the brightest point in the spectrum is in the

yellow λ 600 ca., while in faint light the brightest point shifts well towards the green λ 540 ca. This shift is known as the Purkinje phenomenon. The Purkinje phenomenon also appears in the comparison of single colors. If a red and a blue are equally bright in day light, the blue will be markedly brighter in a faint light. This effect shows even where the lights are combined in a gray which altogether disguises the color. If one gray be mixed of long wave lengths, red and green, and another of blue and yellow and these grays be made of equal brightness in day light, the gray compounded of long wave lengths will be much darker in faint light. It should be said that in light sufficiently faint to give the Purkinje phenomenon, the colors will not be seen as colors, but merely as brightnesses. The spectrum in faint light is a band of gray with a relatively bright spot where the green would be in bright light. That the faint light spectrum is seen with rods alone is evident from the fact that it cannot be seen with the fovea. These three phenomena — different adaptation in periphery and fovea, the lack of color in faint light, and the Purkinje phenomenon — are all to be explained on the assumption that both the rods and the cones give gray, but are differently sensitive to long and short waves. The grays are of approximately the same quality. The only difference noticed is that according to von Kries the gray from the rods has a slightly bluish tone.

**The Different Forms of Color Blindness.** — The distinction drawn between day light and twilight vision, or cone vision and rod vision, has proved very fruitful in the interpretation of certain facts of color blindness. In the long controversy between Hering and Helmholtz a standing point of discussion was as to whether there was ever blindness to red without also blindness to green. Hering insisted that

blindness to one was always accompanied by blindness to the other. Helmholtz regarded red and green as independent colors and asserted that one might be blind to either alone. Observations seemed ambiguous. Most cases saw only blue or yellow, but occasionally careful examination indicated that red would be seen more clearly than the green. When the twilight or rod vision was discovered, it was soon found that in the eye of the totally color blind

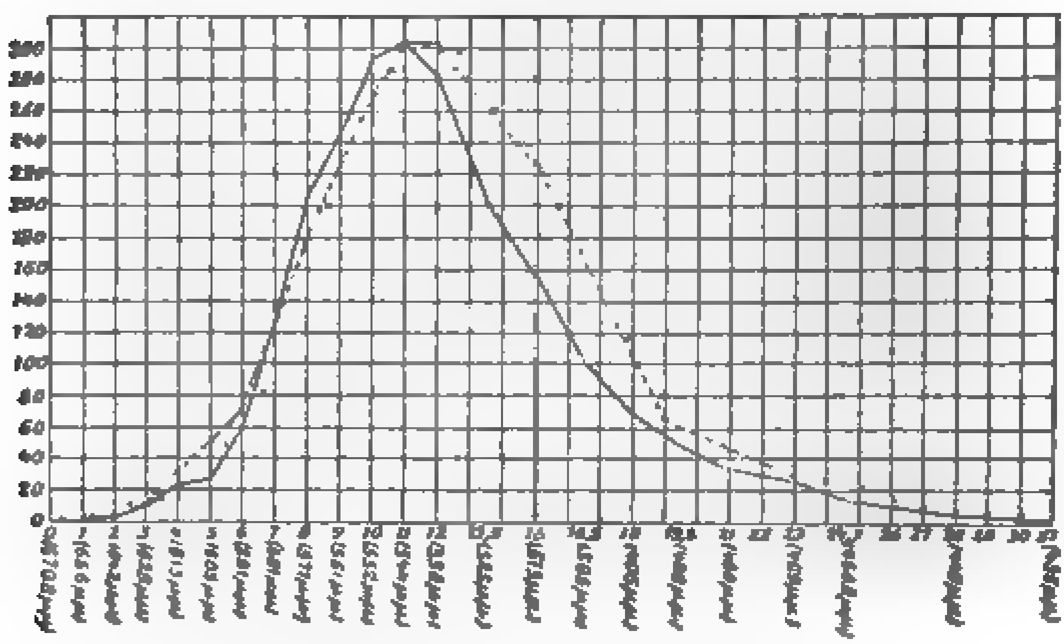

Fig. 46.—Brightness of prismatic spectrum of gas light for total color blind - - - -, and for twilight vision of normal eye ——. Comparison with Fig. 45 shows that both have the same value as the protanope. (From von Kries.)

only the rods were active. The patient could see much better in twilight than in ordinary day light, the relative brightness of spectral waves was the same as that of the normal individual in twilight, and it was shown in a number of cases that he was totally blind in the fovea, where, as has been said, there are no rods. In certain cases the blindness in the fovea was not noticed, but von Kries argues that this was probably due to the difficulty in making observations. Not all would agree that every case of total color blindness is due to lack of function of the cones, but certainly many are.

In the application of this discovery to the cases of partial color blindness, measurement of the brightness values of a number of individuals indicated that the difference between the two types, called by Helmholtz the red-blind and the green-blind, could be traced to the dominance of twilight brightness values, or to the dominance of day light values. Both types were defective in both red and green, but as the red-blind saw the spectrum, the long wave lengths were much darker and so the reds were not noticed. For the other type, the long wave lengths were brighter and they

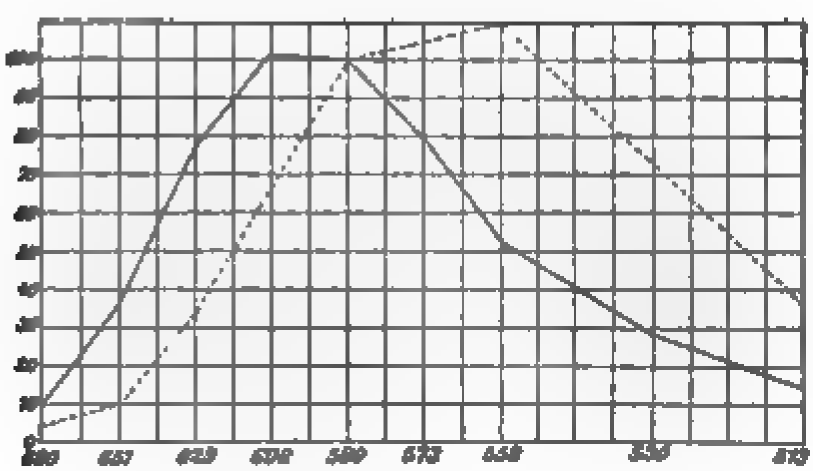

FIG. 47. — Brightness of the gas light spectrum for the periphery of the normal eye ——, and for protanope - - - -. (From von Kries.)

were more likely to see the reds than the greens. To avoid the ambiguities of the older terms von Kries has suggested that those individuals who see the spectrum in the relative brightness values of normal individuals in day light be called deuteranope, those who see it in twilight values shall be called protanope. The brightness values are the same for the protanope, for the totally color blind, and for the twilight vision of the normal eye. On the other hand, the brightness values of the spectrum are also the same for the deuteranopes, the normal eye in day light, and the periphery of the normal eye, as may be seen from the accompanying charts from von Kries (Figs. 46, 47). All this

argues for two kinds of brightness vision, one by the cones, the other by the rods. While the actual sensations of gray given by the two are not to be distinguished, the secondary characteristics are markedly different.

**Temporal Phenomena of Vision.** — The characteristics of a color depend in many ways upon the duration of the color stimulus. Stimuli do not produce their maximum effect at once, nor does the color cease at once with the excitation. There is always a rise to full effect and a gradual disappearance. The course, as has been shown by Miss Bills, is different for each of the colors, both for the period required to attain its maximum, and for the period of decline. The curve varies for each color and for the different intensities of the color. At the lowest intensity used, the order was yellow, red, green, and blue; for the medium intensity it was yellow, green, blue, red; and for the highest intensity, yellow, red, green with blue undetermined.[1] These results were obtained in the dark. They may be different for daylight conditions. When the sensation reaches its maximum, even when the stimulation persists, it begins at once to diminish its intensity, at first rapidly, and then very gradually until all colors disappear. This gradual loss of color, called adaptation, can be easily demonstrated if one will but gaze fixedly at a small square of color. The disappearance of the color of the glass when colored glasses are worn illustrates the same phenomenon. Black and white also show the same tendency. The rate of adaptation varies with the color, so that one component after another may vanish.

After the stimulus is removed, the excitation continues for a moment to be of the same quality as the original, and

[1] Bills, The Lag of Visual Sensation. Monograph Supplement of the Psychological Review, vol. 28.

then gradually dies out. This persistence is called the positive after-image. The dying out corresponds to the period of rise of stimulation. Both may be regarded, and are regarded in all theories, as an expression of the inertia of the color processes. They require time to start and to stop. For a fraction of a second the color or gray persists in approximately full brightness. It is this fact that makes possible the mixture of colors on rotating disks. The excitation of one color persists during the excitation of the retina by the other. For practical purposes the effect is the same as if both lights were active at the same time, and the brightness effect produced is the average of all the lights that are stimulating the eye during the period. If the rotation is less rapid, one obtains a rapid fluctuation in brightness, the flicker. This flicker disappears at a lower rate of rotation when colors are of the same brightness than when they are of different brightnesses. This fact makes it possible to compare directly the intensity of different colored lights, a problem that produces difficulties for ordinary photometric methods.

Aside from this positive after-image, if one gives but a single stimulus of relatively short duration, it will be noticed that there are at least two other images succeeding the first. After a momentary dark period there comes a complementary after-image, usually with an added slightly bluish hue. After another dark interval, an image of the same color as the first and usually fainter appears, to be followed by another dark period. Including the dark periods which look like black it is possible under favorable conditions to see six different images following a colored sector on a slowly rotating disk. These images are an expression of the fact that the retina responds rhythmically, that when a retinal excitation is started it rises and falls in

its response in a regular order. The second of the images mentioned above is assumed to be due to the delayed excitation of the rods, the third to a renewal of the excitation of the brightness organ of the cones.

Interesting also is the fact that it is possible to excite colors as an after-effect of brightness. If one will look for half a second or so at the setting sun and then for a time

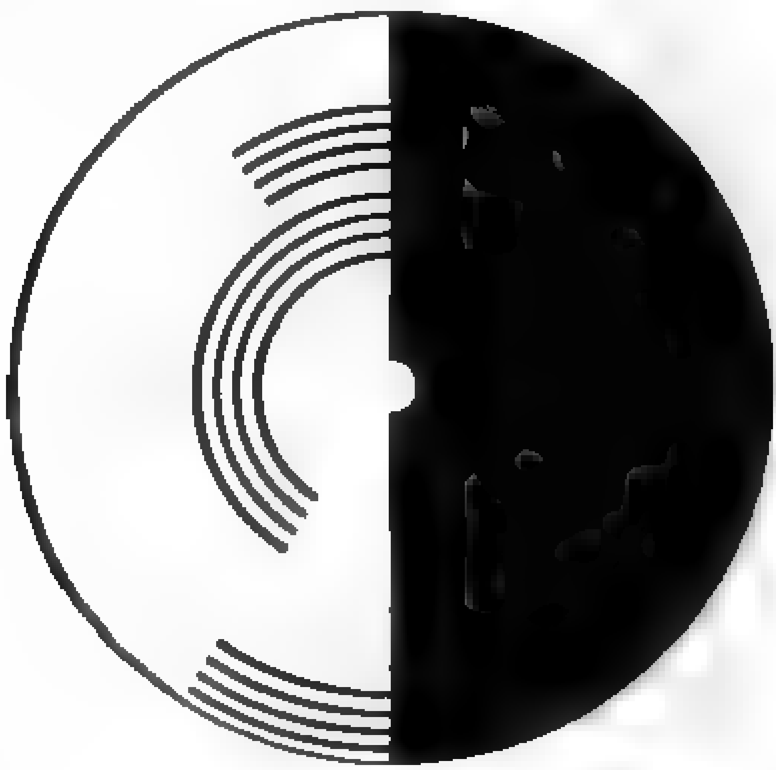

FIG. 48. — Benham disk.

watch the after-image as projected against a neutral surface, one will observe a slow succession of colors and grays that will last for several minutes. Helmholtz gave the order, with the eyes open, as white, red, green, red, blue. One notes in this, too, that the color of an image depends upon the character of the background. It will have a different color with the eyes open and with the eyes closed. When the eyes were closed, Helmholtz found the order to be blue, green, yellow. It will also be noticed when a black and white disk is revolving slowly that a series of faint colors seems

to follow the edge of the black sector. Similar, too, in explanation is the color produced when a white disk with concentric rings of black is rotated. If a disk similar to that in Figure 48 is rotated slowly, the inner ring appears purplish, the outer greenish. The explanation of all these phenomena is somewhat uncertain, but seems to fit best with the assumption of Helmholtz that in some way the color processes are excited by the black and white and that the different colors die out at different rates and so one color will predominate at one time, another at another.

**The Spatial Phenomena of Vision.** — It has been shown that the visual excitation is not limited to the actual duration of the stimulus; its influence is similarly not limited to the area stimulated, but extends about it in all directions to varying extents. A series of facts can be adduced to demonstrate this.

1. Bright colors always look larger than dark ones. A white square on a black ground always looks larger than a black square on a white ground. In each case the white stimulus spreads at the expense of the black. Still more striking is the apparent increase in the size of the filament of the electric light when it glows as compared with its size when cold.

2. A number of small surfaces of two or more colors when in juxtaposition fuse into a color identical with that given by the same colors when mixed by rotation. Each color extends beyond the area stimulated, and these extensions overlap to produce a continuous color of the average hue and brightness of all. The overlapping in space is similar to the overlapping in time in mixtures produced by rotating disks. In many fabrics it will be noticed that the dominant color seen at a distance is a mixture of a number of threads of different colors.

3. A colored surface may be too small to be seen as colored and may yet be seen as gray. Colored objects at a distance lose their color while still visible. The size at which the color disappears varies for different colors. The table below gives the diameter of five colors at which the surface will be seen as gray in the first column and at which it will be seen in color in the second. The column headed "Ratio" gives the proportion between the areas that can be seen at all and the areas that can be seen as colored. It will be noticed that a red surface, which is large enough to be seen at all, is seen as red, while a much larger area of blue is seen only as gray. Several bits of color, each too small to be seen alone, will when close together induce a color sensation. The explanation is the same as for the second law above.

| Color[1] | Absolute Limen | Color Limen | Ratio |
|---|---|---|---|
| Extreme red | 0.5 | 1.0 | 4 |
| Orange | 0.9 | 2.1 | 5.5 |
| Yellow | 1 | 3.1 | 9.6 |
| Green | 0.3 | 4.2 | 196 |
| Blue | 0.3 | 7.5 | 625 |

4. In some degree, size, duration, and intensity are interchangeable. More intense lights seem larger, seem to last longer, and, *vice versa*, within limits larger surfaces and longer exposures seem to give more intense stimulations. Up to two minutes in size doubling the intensity doubles the apparent size.

These various phenomena are to be explained by the spread of the effects of the excitation in the retina, either by a spread of the chemical effects from one unit to another, or by a spread of nervous impulses from the cones or rod stimulated to neighboring ones through the connecting neurones just inside the layer of rods and cones. (See p. 104.) Contrast is due to a similar phenomenon, but has

[1] From Charpentier, Annales d'ocul. lxxix, 1878.

been described above, and the explanation may best be left to the discussion of the various theories, as the induction of a complementary color introduces a new principle.

The Helmholtz Theory. — A brief statement of the more important theoretical explanations of color may serve as a review of the facts. The first of the modern theories was formulated by Thomas Young, an English physicist, and expanded by Helmholtz. It assumes that there are three separate kinds of organs in the retina, that one of these is affected most strongly by red, another by green, and a third by blue or indigo. When all three are excited at once, white is produced. Red and green when stimulated together give rise to yellow. All the other colors are produced by the mixture of the effects of two or all three of the organs. After-images are due to the fatigue of some of the organs and the response of those remaining when white light falls upon the retina. Contrast is an illusion of judgment. The facts are out of harmony with the theory on all but one point. 1. Yellow cannot be a compound color, since yellow may be seen where both its assumed components are lacking, on the periphery of the retina and by the color blind. 2. The same objections hold against regarding white as a compound. It, too, can be seen where no one of its components is present. 3. The explanation of after-images falls with the abandonment of the theory that white is a compound color. 4. Contrast is not an illusion of judgment, as it is most easily noticed where one is not aware that the inducing color is present. The one remnant of the Helmholtz theory is its explanation of color mixing, and the colors that it chooses as primary do not meet any of the physiological tests. The modern adherents of the Helmholtz theory hold also that it explains color blindness, although they admit that the partially color blind see only blue and yellow.

They add to the color processes the rods as an organ for brightness, but still assume that the grays in day light as seen by the cones are a compound of all three colors.

**The Hering Theory.** — The Hering theory asserts that there are two pairs of primary colors with the elements in each pair opposed, and an independent brightness organ. The theory assumes that each pair of colors is produced by antagonistic changes in the same organ. One organ gives rise to red and green, a second to blue and to yellow, and a third to the brightnesses, black and white. The antagonistic processes are said to be anabolism and catabolism, the upbuilding of the organ and its deterioration. Green, blue, and black induce anabolism, the others catabolism. Complementariness is explained by the fact that members of the same pair of colors tend to induce opposed processes in the same degree and so produce no effect. When the tendency of green to produce anabolism and of red to cause catabolism are equally strong, no change in the organ results. Since all wave lengths stimulate the brightness organ, gray is seen, and seen alone, when the colors cancel each other. Color blindness is due to an absence of one or more of the organs. The red-green organ is most frequently lacking. Red-green blindness is most frequent, and red and green are least widely distributed on the retina. In total color blindness the yellow-blue organ is lacking also, the white-black organ alone is present. Positive after-images are explained as due to a continued action of the organ after the stimulus has ceased. In the negative after-image anabolism is followed by catabolism, since the excess material accumulated by the retinal excitation tends to disappear as the light ceases to act and the tissues return to their normal balance. Similarly, catabolism is followed by anabolism when the stimulation ceases. Contrast is

due to one process inducing its opposite in contiguous areas. Excessive anabolism in a stimulated area is at the expense of the nourishment of the other adjoining areas, and catabolism results there.

**Criticism of the Hering Theory.** — The most important objection to the Hering theory is its assumption that the opposed processes are anabolism and catabolism. Nowhere in the bodily structures is anabolism induced by stimulation. If the exact change be left indefinite, be regarded as a reversible chemical process, as Müller and von Kries have suggested, nothing would be lost in adequacy of explanation of the phenomena and much is gained in credibility. A second minor objection, made by Müller, is that it is inconsistent to assume that the opposed processes cancel each other in the color organs, while in the black-white organ they give a sensation, the neutral gray of the rested eye. Müller suggests that the white-black processes cancel each other, so that when there has been no excitation for a long time the retina gives no sensation, but that the cortical cells, the central organ for vision, produce the gray. As evidence for this he cites the fact that the blind, if not blind from birth, always see this gray, and that a spot of gray is seen where even a small area of the retina has been destroyed.

**The Ladd-Franklin Theory.** — A recent theory of Mrs. Ladd-Franklin gives an evolutionary theory of color vision. She assumes that primitive vision in animals is rod vision which gives differences of brightness only. Later cones develop and with them comes the appreciation of colors. Within the cones there is also a development. First appear substances sensitive to blue and yellow alone, then the substance sensitive to yellow divides into two, one sensitive to red and the other to green. Each more evolved organ may

act as a whole to give its original sensation. The cone when stimulated as a whole gives brightness, the red and green acting together give yellow. The color-blind eye is an undeveloped eye. In red-green blindness the yellow substance has not yet subdivided, in total color blindness the cones act only as rods. While very ingenious, its choice of primary colors is open to certain of the objections to the Helmholtz theory, and it fails to recognize the differences between rod vision and cone vision as seen in the Purkinje phenomenon or to explain them in an adequate manner.

We may emphasize certain essential facts which all accept. 1. There are four primary colors, distinguished from the others by the fact that they vanish without change of quality as they are moved outward to the periphery. 2. These four colors are arranged in pairs, red with green, blue with yellow. The pairs cancel when mixed in suitable proportions; one induces the other as an after-image and excites the other on the surrounding areas of the retina. 3. There is an independent brightness which is present in all colors and is seen alone when the colors cancel each other, at low intensities of light, and where the color organs are lacking. Physiologically we may assume an organ for each pair of colors. For this the Hering theory as modified by von Kries is as acceptable as any. That means a single organ for each pair and in each organ opposed chemical processes. The exact nature of the processes must be left undecided. To this must be added the acceptance of a distinction between rods and cones as organs for brightness. They give the same sensations of brightness, but the rods are more sensitive absolutely and are also relatively more sensitive to the short wave lengths; the cones more sensitive to the long.

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# CHAPTER V

## SENSATION (*Continued*)

### Audition

The auditory sensations stand next to the visual, both in complexity and in importance for behavior and mental life in general. We can approach the study of audition in three different ways. Physically, sound is vibration in the air; physiologically, it is oscillation of some delicate membrane in the ear; psychologically, it is the series of sensations, the material of music and human speech on the one hand, and the series of noises and unorganized sounds on the other. The physical processes consist of longitudinal oscillations that proceed outward concentrically from the vibrating body. These oscillations vary in rate, which corresponds to the pitch of the tone; in amplitude, which corresponds to the intensity of the tone; and in complexity, which corresponds to the timbre, or tone-color.

### *The Structure of the Ear*

**The Divisions of the Ear.** — The organ that translates these vibrations in the air into nerve processes is the ear. The ear is composed of three parts: the external ear, consisting of the pinna, commonly called the ear, and the external auditory meatus or tube that runs into the head; the middle ear, an enlarged cavity in the skull separated from the external by the membrane of the tympanum or drum; and the internal ear, a labyrinthine cavity between the middle ear and the brain where the vibrations are trans-

lated into nervous impulses. The external ear needs no description. The outer ear probably has some influence in collecting the vibrations in the air and turning them into the external meatus. The meatus itself is curved slightly and thus reduces to a minimum the probability of injury to the membrane of the tympanum.

The important structures of the middle ear are the membrane of the drum, three small bones that stretch across

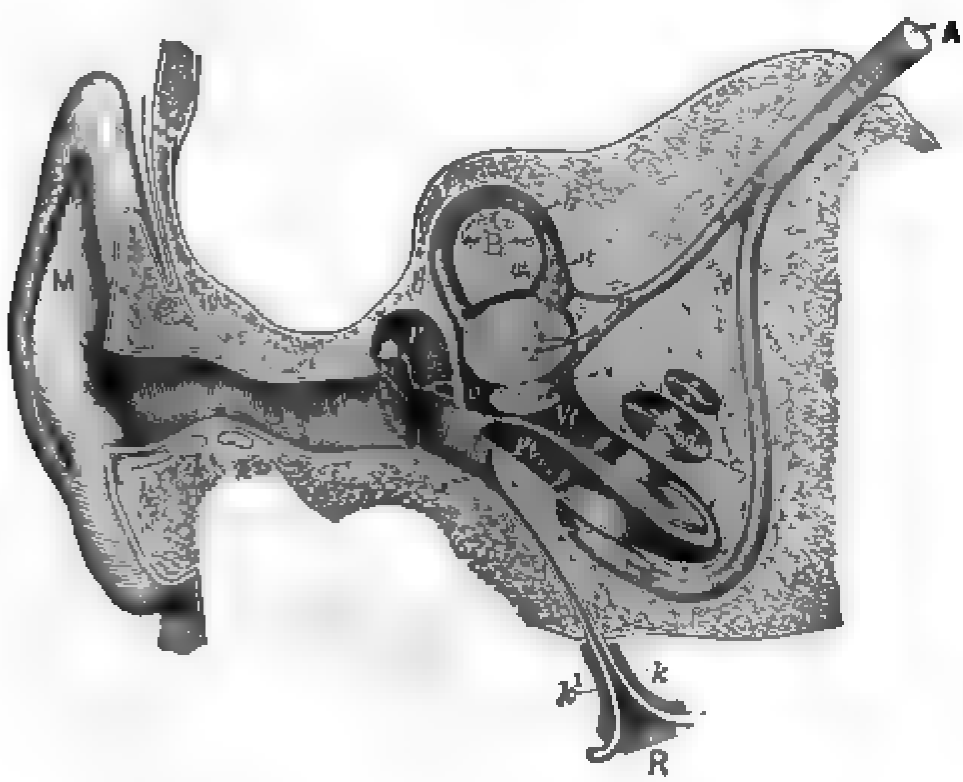


FIG. 49. — Schematic section of the ear; *M* and *G*, external ear; *P*, middle ear with small bones; *S*, cochlea; *B*, semicircular canal; *A*, auditory nerve; *R*, Eustachian tube. To give a sectional view the cochlea is displaced 90°. Its apex should be turned toward the observer. (From Calkins, after Martin-Czermak.)

the cavity of the middle ear, and the membrane which with the plate of the stirrup closes the oval window of the inner ear. The chain of bones consists of the malleus, incus, and stapes, named from their shapes, which resemble a hammer, anvil, and stirrup, respectively. The handle of the hammer is fastened to the inner surface of the membrane of the tympanum, the head is jointed into the top surface of the

anvil, not unlike a large molar tooth in shape, and is hung by a ligament from the top of the cavity of the middle ear. The stirrup is attached by a delicate cartilage to a process of the anvil, not unlike one of the roots of the tooth. The

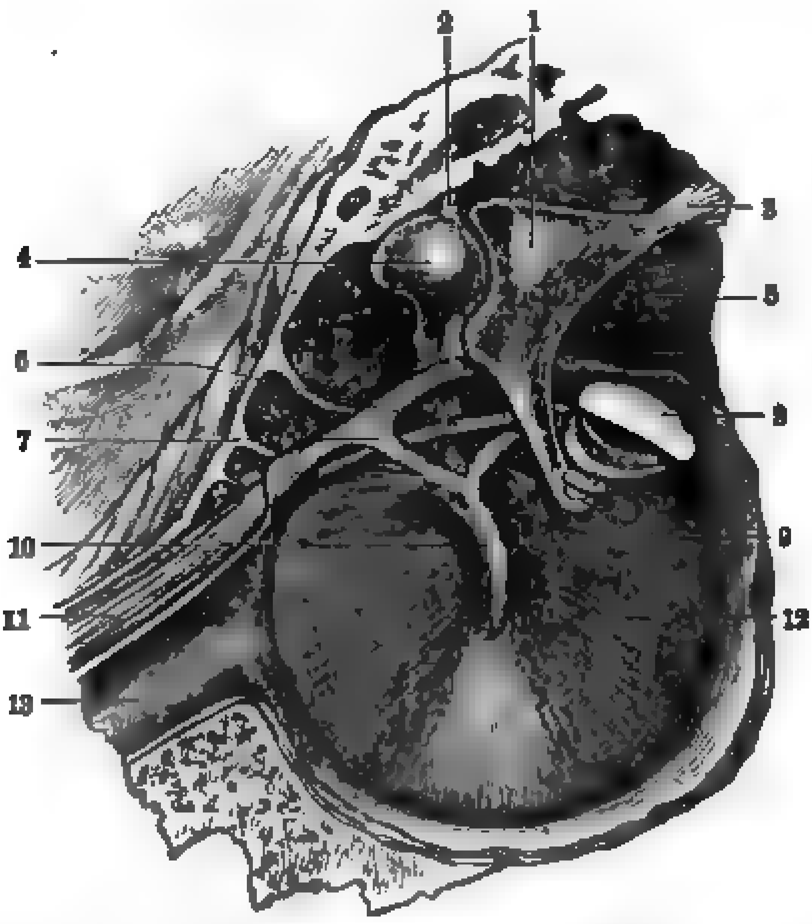


Fig. 50. — Tympanum and small bones seen from within the middle ear. 1, anvil, 2, suspensory ligament of hammer; 4, head of hammer; 7, tendon of tensor tympani; 8, foot piece of stirrup that fits into the oval window, 10, handle of hammer or manubrium; 11, tensor tympani; 12, membrane of the drum; 13, Eustachian tube.

membranes and the bones swing together on the ligament as a fulcrum. When the air vibrations impinge on the membrane of the drum, it swings inward, carrying the hammer and the other bones with it, and the foot of the stirrup pushes against the lymph of the inner ear, and sets that in vibration also. Two muscles prevent movements strong enough to rupture either membrane. One, the tensor tym-

pani, extends laterally from a bony canal inside of the tympanum and is inserted in the head of the hammer; the other, the stapedius, extends from a tube in the lower inner wall of the cavity and is inserted by a long ligament in the head of the stirrup near where the anvil is joined to it. The two muscles oppose each other. The tensor tympani tends to draw the drum head inward, the stapedius to draw the stirrup foot away from the oval window toward the drum head. When both contract, the entire vibrating mechanism is held firm and prevented from making too violent oscillations.

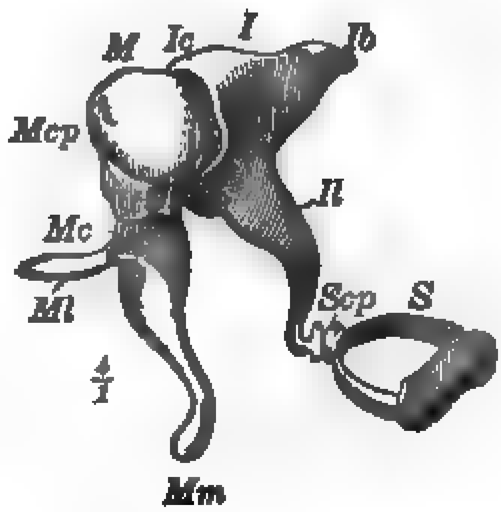


FIG. 51. — The bones of the middle ear. *M*, hammer; *I*, anvil; *S*, stirrup.

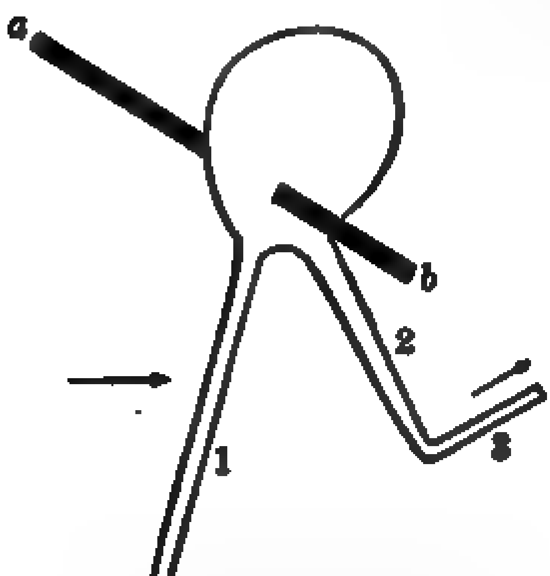


FIG. 52. — Illustrates the way in which the three bones act together as a bent lever. 1, the handle of the hammer, 2, the long process of the anvil; 3, the stirrup; *a–b*, the axis of rotation. (From Howell's "Textbook of Physiology.")

The membrane of the drum, by virtue of its conical shape, the arrangement of the fibres that compose it, and the weighting on one side only, has no tone of its own, responds to all vibration rates impartially, and so transmits all tones, whatever their pitch, with approximately equal strength. In traversing the middle ear, the amplitude of the waves is decreased and their intensity increased. This change

takes place in two ways. First the area of the oval window is much smaller than the area of the drum, so that the energy is more concentrated. Second, as can be seen in Figure 53, the lever arm formed by the handle of the hammer has a greater effective length than that formed by the process of the anvil to which the stirrup is attached. Sound waves, then, traverse the oscillating mechanism of the middle ear with rate or pitch unchanged but with intensity increased twenty to thirty times and with a corresponding diminution in amplitude. An essential mechanism for making possible the vibration of the drum and for protecting it against rupture due to difference between the air pressure in the outer air and that within the middle ear is the opening into the throat provided by the Eustachian tube. This serves to keep the pressure of the air in the middle ear approximately equal to that in the outside world. The act of swallowing opens the tube and permits the interchange of air.

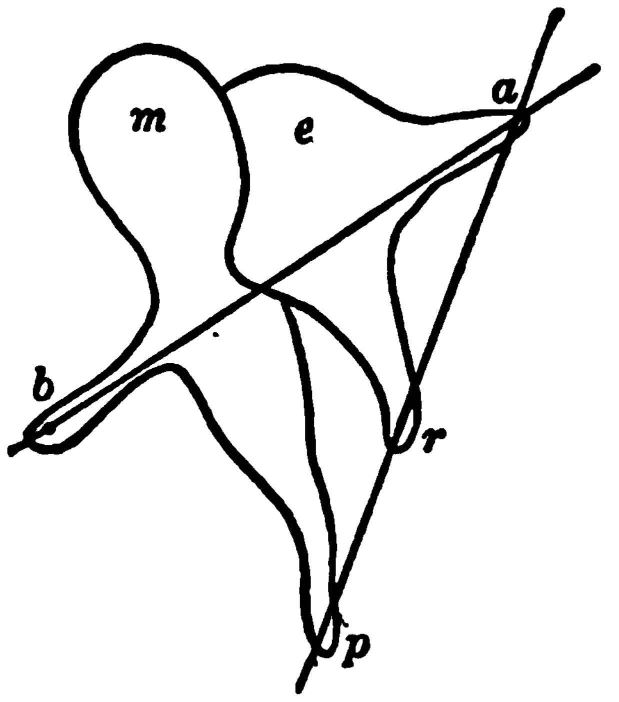


FIG. 53. — To illustrate the lever action of the ear bones. *m*, the hammer; *e*, the anvil; *a*, the short process of the anvil which abuts upon the wall of the middle ear and serves as point of rotation; *a–b*, the power arm; *a–p*, the load arm of the lever.

**The Cochlea.** — The inner ear, or labyrinth, is filled with lymph. It has two openings into the middle ear, both closed by delicate membranes. One we have mentioned as receiving the foot of the stirrup. The joint is made watertight by a membrane. This is the oval window. The other, a little below the oval window, is closed by a single membrane. From its shape it is called the round window. We may dis-

tinguish two parts of the inner ear, the cochlea and the labyrinth proper, — the semicircular canals, utriculus, and sacculus. As the *cochlea* alone is concerned in hearing, a

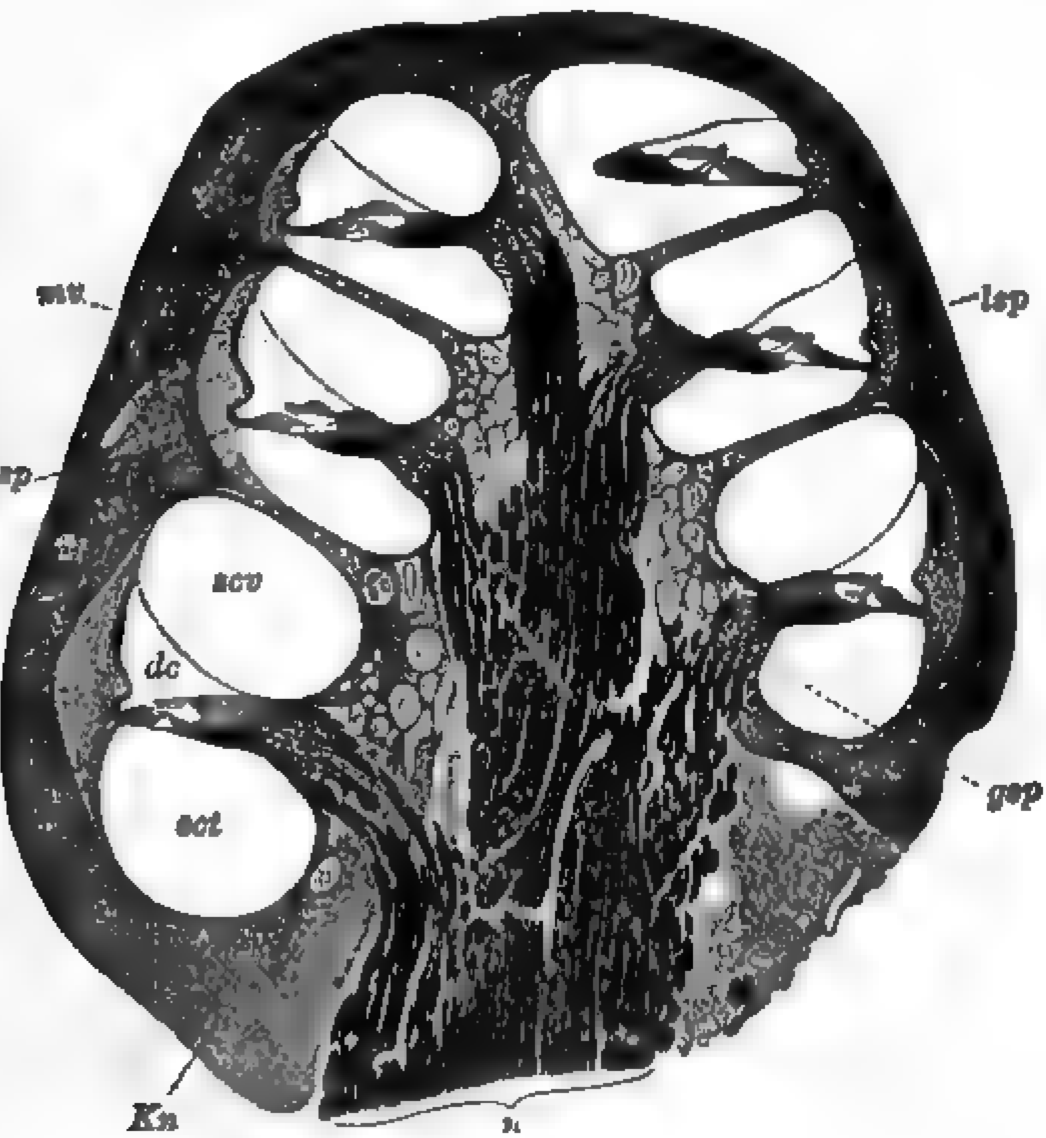


FIG. 54. — Longitudinal section of the cochlea of a cat; *dc*, cochlear duct; *gsp*, spiral ganglion; *msp*, membrana spiralis (basilar membrane); *mv*, Reissner's membrane; *n*, cochlear nerve; *sct*, scala tympani, *scv*, scala vestibuli. (From Huber, after Sobotta.)

description of the other structures may be postponed. In essentials the cochlea is a tube divided up its middle by a partition of bone and membrane. One side of the partition is closed by the oval window, the other, or lower, by the round window. The tube is wound two and a half times

about a central column of bone, the modiolus. The cochlear nerve, the nerve of hearing, enters the centre of the modiolus, and ascends to the top, giving off a spiral band of nerves from the bottom to the top of the cochlea. It enters through the spiral ridge of bone, the lamina spiralis, and ends in close connection with cells tipped with hairs on and about the basilar membrane. This basilar membrane, together with the lamina spiralis, constitutes the dividing partition of the cochlear tube. If one looks at a section of the cochlea, one sees five or six sections of the tube (Fig. 54). In each of these there are three divisions. The upper one in the figure is called the scala vestibuli, the staircase of the vestibule, since it connects directly with the vestibule and the oval window. A small triangular canal is divided off by the basilar membrane and a delicate membrane above it, Reissner's membrane. This is the cochlear canal. Below the basilar membrane is the scala tympani, which connects with the round window. The vibrations of the stirrup are transmitted to the lymph through the oval window, and ascend to the top of the cochlea by the scala vestibuli. At the apex is an opening between the scala vestibuli and the scala tympani, which is supposed to permit the vibrations to pass from one to the other. The delicate membrane of the round window permits the liquid to vibrate as it could not were there but one opening to the cavity filled with liquid. By virtue of these connections, the liquid in the cochlea vibrates at the rate of the sound wave in the air.

## *Sensations of Tone*

**The Qualities of Tone.** — The problem for the theory of hearing is how the vibrations in this liquid in the cochlea may excite the auditory nerve. To answer this question we must turn to a consideration of the facts of auditory

sensation. The qualities of tone run in a single line from low to high. Slow vibrations give low tones, rapid vibrations high tones. The lowest tones that can be heard vary from about twelve to sixteen per second. The upper limit was given by Galton at 50,000, by Preyer at 40,000, Bruner from 22,000 to 43,000 for different individuals, while Edelmann asserts that some individuals can hear 50,000 vibrations. Later investigators, working with more accurately tuned instruments, which however probably give less intense tones, obtain values about 20,000 vibrations per second. The lower tones are determined by means of large forks, the upper usually by a whistle with very short barrel, first devised by Galton, of which a new and more accurate model has recently been made by Edelmann. The intermediate tones increase regularly in pitch.

The accuracy with which the pitch of tones may be distinguished varies markedly with the absolute pitch. Tones in the middle range can be discriminated much more easily than very high tones or very low tones. From 64 to 1024 V D,[1] one can distinguish differences as small as 0.3–0.2 of a vibration. Above or below this, tones must be much more different to be distinguished. At 32 and 2048 V D the addition of 0.4 of a vibration can just be noticed, and for very high and very low tones, many vibrations may be added before a difference is noted. One can distinguish tones differing by these amounts and even say which is higher and which lower. On the basis of these experiments by Preyer, Luft[2] and Max Meyer[3] it has been estimated that one can distinguish approximately 11,000 different pitches.

[1] V D means double or complete vibrations.

[2] Philosophische Studien, 4, 511 ff.

[3] Zeitschr. f. Psychol. u. Phys. d. Sinnesorg. 16, 352 ff.

**The Octave.** — Within the range of audible tones there seem to be critical points similar in a way to the critical points in the spectrum. In the sound series these critical points are the octaves of the musical scale. The octave corresponds to the spectrum. As one may say that the ends of the spectrum are more similar than the middle to either end, so double the vibration of any tone gives a note that is more similar to it in one respect than the intermediate tones. These octaves constitute, for the trained ear at least, regularly recurring similar tones. Within the octave the notes whose vibration rates form a ratio of 2:3, 3:4, 4:5, etc. with the lower note of the octave constitute other marked resting points or qualities which are recognized at once by the musically trained. Trained ears are more likely to make a mistake of an octave in the note than to mistake one note for another within the octave. This may possibly be due to special training, as many other systems of music, the Chinese, for example, seem not to recognize the same distinctions, but the balance of evidence at present seems to favor the view that the distinction is fundamental.

**Tone-color.** — Two other differences in the quality of tones may be mentioned. One, that tones of the same pitch from different instruments have a characteristic difference ordinarily spoken of as timbre or tone-color, which depends upon the overtones that are added to the fundamental. Thus in the C of 64 double vibrations from a piano string there are also found the c of 128, the g of 192, the c′ of 256, the e′ of 320, the g′ of 384, the seventh overtone of 448 which does not correspond exactly with any note in the scale, the c″ of 512, etc. Every multiple of the rate of vibration of the fundamental is represented, theoretically, since they correspond to the nodes in which the sounding body vibrates, and these nodes are formed at each small

fraction of the length of the surrounding body. The first ten overtones can be readily heard when intensified by resonators. If one will hold down a key on the piano that corresponds to one of the overtones, one can hear that overtone continue to vibrate after the fundamental has been dampened by dropping the key. It is started into vibration by resonance and continues to vibrate for a time after its excitant has stopped. With practice one can hear the overtones separately with the unaided ear. Each instrument has its own arrangement of overtones, and these give it its timbre. The tuning fork has almost none; in the piano they are present in fairly even strength, while in the violin certain of the high ones are emphasized at the expense of the lower. Each of the musical instruments owes its peculiar quality to the number, pitch, and relative strength of its overtones.

**Vowel Qualities.** — The characteristic differences of vowels can be given a similar explanation. Helmholtz and König believed that they were due to the presence or absence of overtones. The overtones were emphasized by the resonance of the mouth chamber which is changed in shape by the contraction of certain muscles. This supposition was confirmed by synthetizing vowels, — for example, by putting together simple tones to constitute the fundamental with its overtones. Recently there has been revived by Köhler[1] an old theory of Hermann that vowels are not due to the presence of overtones of the fundamental note of the tone, but that the characteristic of the vowel was some single note which does not change with the pitch of the fundamental, as would be necessary if it were an overtone. These characteristic notes were called formants by Hermann and were assumed to be developed by the air blown

[1] Köhler, Zeitschrift f. Psychologie, vol. 54, p. 280.

through the mouth cavity, which is given a different form for each vowel. Köhler tested a number of individuals by giving them a series of tones which could be gradually changed and asking them to say when the tone took on a vowel or consonant character. His results indicated that the vowels were about an octave apart through the scale. In order he gives the following notes as the characteristic tones of vowel sounds: $m = 130$, $u = 260$, $o = 520$, $a = 1040$, $e = 2080$, $i = 4100$, $s = 8200$, $f = 17{,}000$, $ch = 34{,}000$. All the values are approximate only and the sounds are the sounds of the German letters. Between the pure vowels are mixed ones. One shades gradually over into the other and both elements can be distinguished. Dayton C. Miller,[1] by an objective method, found some of these notes to be present in the vowels but not all. He, however, accepts the Helmholtz overtone theory of vowels. Not only does this theory serve to explain the vowel sounds, but it explains the characteristic differences in the series between the octaves. The notes repeat themselves in the octaves, and the beginning of the repetition is marked by the change from one vowel tone to another. It is suggested that the sensations corresponding to increased vibration rate may be pictured as a spiral, with the same notes over each other.

**Beats.** — An effect of combinations that is purely sensational is found in the beat. If two tones of approximately the same pitch are sounded together, there is heard an alternate increase and decrease of the tone which comes as many times a second as the difference in the number of vibrations per second of the component tones. Physically this is due to the fact that the component tones will be alternately in the same phase and in opposite phases. When

[1] Dayton C. Miller, Science of Musical Sounds, pp. 219–243.

they are in the same phase, the resultant will be the sum, when in opposite phases, the difference, of the two tendencies to vibrate. When these alternations come some distance apart, they are heard as distinct swellings and diminutions; when closer together, merely as a roughness of the tone. For the theory it is interesting to note that most beats seem to be carried by neither of the tones themselves, but by a tone intermediate between the tones that produce the beats. This we must come back to later.

**Tonal Fusion.** — Of the various phenomena that were mentioned in connection with vision, some are also to be noticed in sound. The phenomena of mixture of colors is replaced by fusion of tones. The two are not easily comparable, since the result of the combination of tones is dependent upon the position of the notes within the octave also. Each note in a fusion can with a little practice be heard separately; there is no fusion that gives an intermediate tone as in color, and no cancellation, no phenomenon allied to complementariness. The degree of fusion of the whole depends in large measure upon the ratio of vibration rates of the two tones; the smaller the numbers that represent the ratios, the closer the fusion. The best fusion is furnished by the octave, whose components give a vibration rate of 1 : 2, the fifth, 2 : 3, and decreases with the ratios represented by larger numbers as the second, 8 : 9; the seventh, 8 : 15, etc. This relation holds at least approximately, although critics have insisted that the degree of fusion in certain combinations does not correspond accurately to the smallness of the numbers that express the ratio of vibration rates. Closely related to fusion is consonance or the availability of the combinations for musical effects. This depends partly upon the degree of fusion, more upon

the training of the hearer. This dependence upon training is shown by the difference in what is regarded as pleasant between occidental and oriental music and in the gradual change in the accepted intervals in western music. The tritone, the fourth, and the fifth, the only intervals used by the Greeks, have gradually given way to the thirds and sixths, and now we see seconds and sevenths admitted to music under certain circumstances. It is the feeling tone, as well as the physical combinations, that determines the effect.

**Helmholtz Theory of Consonance.** — An explanation of consonance is given by Helmholtz on the basis of beats. The notes that give the most perfect fusion are themselves far enough apart not to beat and, furthermore, do not give rise to beats between their overtones. Thus the fifth with a ratio of vibrations of 2 : 3 would have as overtones of the first components 4, 6, 8, 10, etc., and as overtones of the second component 6, 9, 12, etc. Of the first four overtones only the 8 and 9, 9 and 10 would be near enough to beat or be dissonant, and two of the first four would be identical, the others no less consonant than the fundamentals themselves. On the other hand, the major seventh, with a ratio of 8 : 15, while giving no beats between the fundamentals, would have beats between most of the overtones. The fundamental of the higher, 15, would beat with the first overtone of the second, 16, the third overtone of the lower beats with the first of the higher, and in general there are many beating overtones and no identical ones below the eighth of one and the fifteenth of the other. In general, then, dissonant chords may have beats either between the fundamentals or the overtones, while consonant chords have few beats if any between either fundamentals or overtones.

**After-sensations.** — Like colors, tones have after-sensations, but only positive ones. It requires some time for a tone to reach its maximum, and also it persists some little time after the physical excitation ceases. The ear is much more rapid in its adaptations than the eye, however; it has much less inertia. According to Mayer separate tones can be heard if they are repeated as frequently as 27 per second for notes of 64 V D and 204 times per second for a note of 1024. There are also intermittent after-sensations of tones, but they are not so often noticed as after-images. Urbantschisch reports that single primary after-tones may last from one to ten seconds. The intermittent after-images may follow each other at irregular intervals for one to two minutes. Each after-sensation will last from 10 to 15 seconds at intervals of from 10 to 20 seconds. Usually these intermittent tones are of the same pitch as the objective tone, but some may be higher or lower. They are fainter than the original and usually fluctuate in intensity.

Corresponding to color blindness are rare cases of what are called tone islands, — the patients deaf to large portions of the scale who can hear notes of intermediate pitch. More frequent are individuals whose range of audition is shortened above and below, and it is a fairly general rule that the upper notes gradually cease to be heard with increased age.

**Combination Tones.** — An interesting phenomenon of hearing is furnished by combination tones. When two notes are sounded, one frequently hears, in addition to the notes themselves, tones that correspond to the difference between their vibration rates or to the sum of their vibration rates. Thus if the tones c and e of 128 and 160 be sounded together, one will hear a note corresponding to the difference in their vibration rates, 32. One can also

hear a second difference tone whose rate is the difference in rate between the higher and twice the lower ($2\,l - h$) of 96 and a third tone ($3\,l - 2\,h$) of 64. Some authorities report that they hear fourth and fifth difference tones named on the analogy of the last. The striking aspect of these tones is that in part at least they are subjective; they cannot be heard more clearly by means of resonators than by the unaided ear, and all other means of demonstrating their objective existence fail. They must apparently be accounted for by the physiological or psychological theory of hearing. Another combination tone is the summation tone. This is a note that corresponds to the sum of the vibration rates of the component tones. It is not so easy to hear as the difference tones, and it is more difficult to obtain pure conditions for it, as in many cases it will correspond to an overtone or to a difference tone between the overtones. The summation tones are probably of subjective origin, but no satisfactory explanation has been given of how they originate.

**Tone and Noise.** — The other even more fundamental difference in sounds is that which obtains between tones and noise. The difference is sufficiently familiar to need no description. Physically as well as psychologically two forms of noise are to be distinguished. The more usual is due to a very complex mass of tones that have no simple relation in their vibration rates, and have even been said to be nonpendular in character. Any inharmonious combination of many tones is accepted as noise. A noise of this kind passes gradually over into tone, as the degree of dissonance is lessened, or the tonal element comes to predominate. If there are any tones that are not reducible to the ordinary pendular or sine form, they may also be present in noise. That complex sounds like the sawing of wood or the rattle

on a city street are merely tones in great number and variety without any harmonic relation is probable, since with resonators one can distinguish tonal elements in them. The second type of noise corresponds to a simple vibration too short to produce the full tonal character. Upon cutting off a pure tone after only one or two full vibrations have been made, a sudden noise is heard, which lacks the tonal character. This is usually done by passing the tone through a tube that can be opened to permit the sound to pass for only a fraction of a second. When less than two full vibrations reach the ear, the effect is a shock. The full tonal character of the sound is obtained only when sixteen full vibrations are heard. Noise and tone, then, are different only in the time of stimulation or in the arrangement or combination of the elementary waves, not in the character of the waves themselves.

**Theories of Hearing.** — The physiological theory can be discussed only in connection with the structures about the endings of the auditory nerve in the cochlea. As was said, the auditory nerve enters the centre of the modiolus about which the cochlear canal is wound, and the sheet of fibres extends through the lamina spiralis to end in the neighborhood of hair cells on the basilar membrane. The structures here are somewhat complicated, but the theories have made no use of most of the complications. The membrane that helps to divide the cochlea into two canals consists in large part of transverse fibres. These for Helmholtz constitute the essential part of the basilar membrane. Below them is a layer of connective tissue which is thicker than the layer of fibres. On the basilar membrane are found several peculiar structures. The most striking of these are the rods of Corti. These consist of two rows of delicate structures curved and fitted together at the top to form a

clearly defined arch. They leave an opening between them, the canal of Corti. These rods are not continuous longitudinally and are considerably less numerous than the fibres of the basilar membrane. On the inner side of the arch is one layer of cells with a tuft of hair at the top; on the outer side are four or five layers, with similar tufts that extend through a membrane, Kölliker's membrane, to the lymph of the cochlear canal. Covering the outer portion of the basilar membrane are relatively thick epithelial cells.

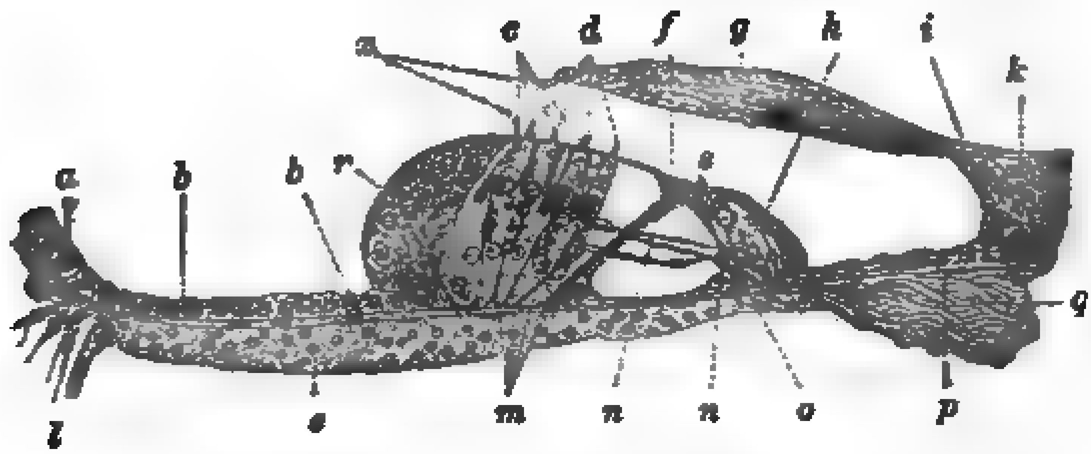


FIG. 55.—Organ of Corti. *b*, basilar membrane; *d*, outer auditory or hair cells; *e*, inner auditory cell; *f*, top of outer rod of Corti, forming one side of the arch of Corti; *o*, inner pillar cell; *g*, tectorial membrane; *q*, nerve fibres; *n*, nerve fibres extending across the canal of Corti. (From Huber after Retzius.)

On the inner side, extending out from and well above the lamina spiralis, is a delicate membrane, the tectorial membrane, which hangs free in the liquid above the entire width of the differentiated mechanisms. These can all be made out in Figure 55.

On first sight one would think that the rods of Corti must be the essential organ of hearing. They are so highly developed and delicate that a teleologist would insist that they must have some specific function.

The most fully developed theory is that of Helmholtz. In essentials it assumes that there must be in the ear resonators tuned to each tone heard. An analogy can be

drawn with the piano strings which vibrate in sympathy with the tones that are present in the outer air. If one speaks in a room with a piano, the tones of the voice will be heard sounding after the voice has ceased. If one will hold down a key and sing, the corresponding note will be distinctly heard to respond in sympathetic vibration. Helmholtz believed that there must be resonators in the ear which respond in the same way to the vibration for which they are tuned. His first idea was that the arches of Corti must be these organs. When they were counted, however, it was found that there were only 3000 of them, while it was known that some 11,000 tones could be heard. Helmholtz then turned for his resonators to the fibres of the basilar membrane. These are sufficiently numerous (18,000–24,000) to provide a resonator for each tone that can be heard. They also show some difference in length, — at the upper end of the cochlea they are approximately 0.48 mm. long, at the lower end about 0.04. This is not difference enough to account for the difference in pitch that they are supposed to show, but Helmholtz assumed that they were differently loaded and tuned by that means for the different tones.

In the completed theory, then, it was assumed that in the basilar membrane are fibres, or really sections of the membrane, tuned to each note heard. The various complex vibrations are impressed upon the liquid of the inner ear by the oscillations of the stirrup, and these are analyzed into their parts by the fibres. In a piano tone, or other note rich in overtones, a separate fibre is set into vibration by the fundamental and by each of the overtones; in a chord each component similarly arouses a different fibre or group of fibres and each is sent to the centres by a separate nerve. The vibrations of these fibres serve in some way not made very clear to stimulate the nerve fibres between the hair

cells. The vibration of the fibres is dampened by the tectorial membrane, which is assumed to drop down upon them when the sound ceases. Noises were at first assigned to the vestibular structures, but when these were discovered to have another function, they too were regarded as due to excitations of many fibres in the basilar membrane. Indirect evidence was found to support the theory in the fact that in cases of deafness to part of the scale, parts of the basilar membrane were likely to be diseased. Von Bezold has found that patients who have the so-called tone islands, parts of the scale that they can hear, while deaf to most notes, also are found after death to have lesions in the corresponding part of the basilar membrane. In the aged the lower part of the basilar membrane is often in a pathological condition, and they fail to hear high tones.

**Details of Helmholtz's Theory.** — The theory is adapted to explain a number of the facts of hearing. Beats may be regarded as due to an overlapping of the vibrating portions of the membrane, and thus as giving rise to an interference phenomenon in the intermediate fibres. On this assumption each tone would cause a ribbon of several fibres to vibrate instead of a single fibre as Helmholtz first asserted. When they were near together, the outer edges of the two ribbons would have common fibres. These would tend to vibrate with the rates of both notes, and the interference of the two movements would cause the beats. This view receives support from the fact mentioned earlier that it is a note intermediate between the other two that beats rather than either of the component tones. It is the intermediate fibres that are vibrating at two different rates and consequently carry the beats. When the vibrating ribbons are sufficiently far apart there are no interferences and so no beats.

The explanation of difference tones is not so satisfactory. Helmholtz at first thought they might be beat tones, misled by the fact that there would be as many beats per second as the vibrations per second of the difference tones. This was given up when it was seen that the beats could not stimulate the corresponding fibre in the basilar membrane. His final explanation was that they must be produced in the middle ear. He demonstrated by a differential equation that a membrane loaded on one side alone when excited simultaneously by two rates of vibration should produce a third vibration that corresponds in its rate to the difference between the rates of the two components, but he did not point out the physical correlates of his mathematical values.

On the whole the Helmholtz theory is the most detailed; it accounts for more facts than the others and receives more incidental support. Its weakness is a conflict with the anatomical findings. The basilar membrane does not consist of a series of delicate fibres hanging relatively free and separated from each other. Instead, the fibres are embedded in a mass of tissue on both sides thicker than the fibres themselves. Ayres tested the possibility of the basilar membrane's vibrating to tones on the ear of a criminal who had just been executed, and found that even with this perfectly fresh material and the most favorable conditions no vibration in the basilar membrane could be detected.

**Telephone Theories.** — Other theories abandon the resonator principle, assuming instead that some structure in the cochlea must vibrate as a whole and the analysis of the separate tones be made by the cortical centres. Hensen and Rutherford have assumed that the basilar membrane, acting much like the plate of a telephone, transmits the

complex notes to the cortex where analysis takes place. Max Meyer has a somewhat similar theory. His assumption is that the intensity of the tone is determined by the distance the vibration extends inward from the oval window, while the quality is determined by the rate of vibration of the membrane as a whole. Hardesty[1] has abandoned the basilar membrane as the vibrating mechanism and assumes that the tectorial membrane is the receiving organ. Hardesty argues that the vibrations of the liquid are taken up by the tectorial membrane and communicated to the hair cells and thence carried to the brain, where, as in the other theories of this type, analysis takes place. The difficulty with this whole group of theories lies in the assumption that differences in vibration rate so slight as one in ten thousand should be appreciated by the cortex, while the most delicate appreciation of differences in intensities is one in a hundred. The difference in intensity that can be appreciated by the ear is only one in five. On teleological grounds, which of course have little weight, it seems inexplicable that the extension of the auditory nerve over such a wide area with relatively complicated end organs should have no particular function.

It can be seen that in spite of the ingenuity and assiduity of investigators and theorists, a satisfactory theory of hearing is yet to be developed. The Helmholtz theory has the advantage of all the others in the number of facts that it explains and the detailed nature of its explanation; it suffers from the improbability of its demand that the fibres of the basilar membrane vibrate separately. On the other hand, the theories that give a plausible explanation of the way the anatomical structures may act make large

[1] Hardesty: On the Nature of the Tectorial Membrane, etc. American Journal of Anatomy, Vol. VIII, p. 109.

demands on our ability to distinguish differences between vibration rates.

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## TACTUAL SENSATIONS

**Cutaneous Sensations.** — The sensations from the skin are simplest of all, and their organs are most accessible, but only in the present generation have the more important facts concerning them been discovered. The same distinctions between physical stimulus, physiological processes, and sensations, that we have been compelled to make in the other senses are to be drawn here. The adequate stimuli for the skin are mechanical and thermal. But while the stimuli vary only in intensity, different sense organs are affected by different intensities, and corresponding differences in sensation result. This is most marked in the temperature sense. The physicist assures us that cold is nothing positive, but merely a reduction in the amount of heat. Nevertheless when the temperature is reduced below about 30° C. a sense organ is excited which gives rise to the sensation of cold, and this sensation increases as the temperature is lowered. Above 30° another organ is stimulated and its activity increases as the temperature rises. Similarly, slight mechanical stimuli excite sensations of pressure;

and intense ones, sensations of pain. We then have four distinct sense qualities, while there are but two kinds of physical stimulus. More clearly than in any other organ can the sense qualities be shown to depend upon the organ stimulated.

### *Temperature*

The discovery of the distribution of the organs, and with that the settlement of most of the problems of cutaneous sensibility, is a matter of comparatively recent date. It came first in the temperature senses. At approximately the same time and altogether independently of each other three investigators, Blix, a Scandinavian (1882), Goldscheider, a German, and Donaldson, an American (both 1885), found that the skin was sensitive to temperature only in relatively isolated spots rather than all over, as had been earlier supposed. The skin was carefully tested point by point with a cooled or heated metal point, and it was found that at certain points irregularly arranged one would feel cold, at others, warmth. The most important disagreement in the results found was between Goldscheider on the one side and Blix, with practically all later workers, on the other. Goldscheider found warm and cold points to be thickly scattered everywhere on the skin; for example, on the back of the hand there were 68 cold spots and 56 warm spots on a square centimetre. Blix reported that they were much farther apart, and all later investigators have confirmed his results. Sommer counted carefully the number in many square centimetres and found that there were from 6 to 24 cold spots, and from 0 to 3 warm spots, to the square centimetre. He gave as his average 12 to 13 cold and 1 to 2 warm spots. His estimate for the whole body was 250,000 cold and 30,000 warm spots.

**Indirect Evidence of the Existence of Warm and Cold Spots.** — Many of the earlier theories assumed that there must be a single organ for warmth and cold. Hering, for example, had a theory which would make warm and cold depend upon assimilation and dissimilation in the single

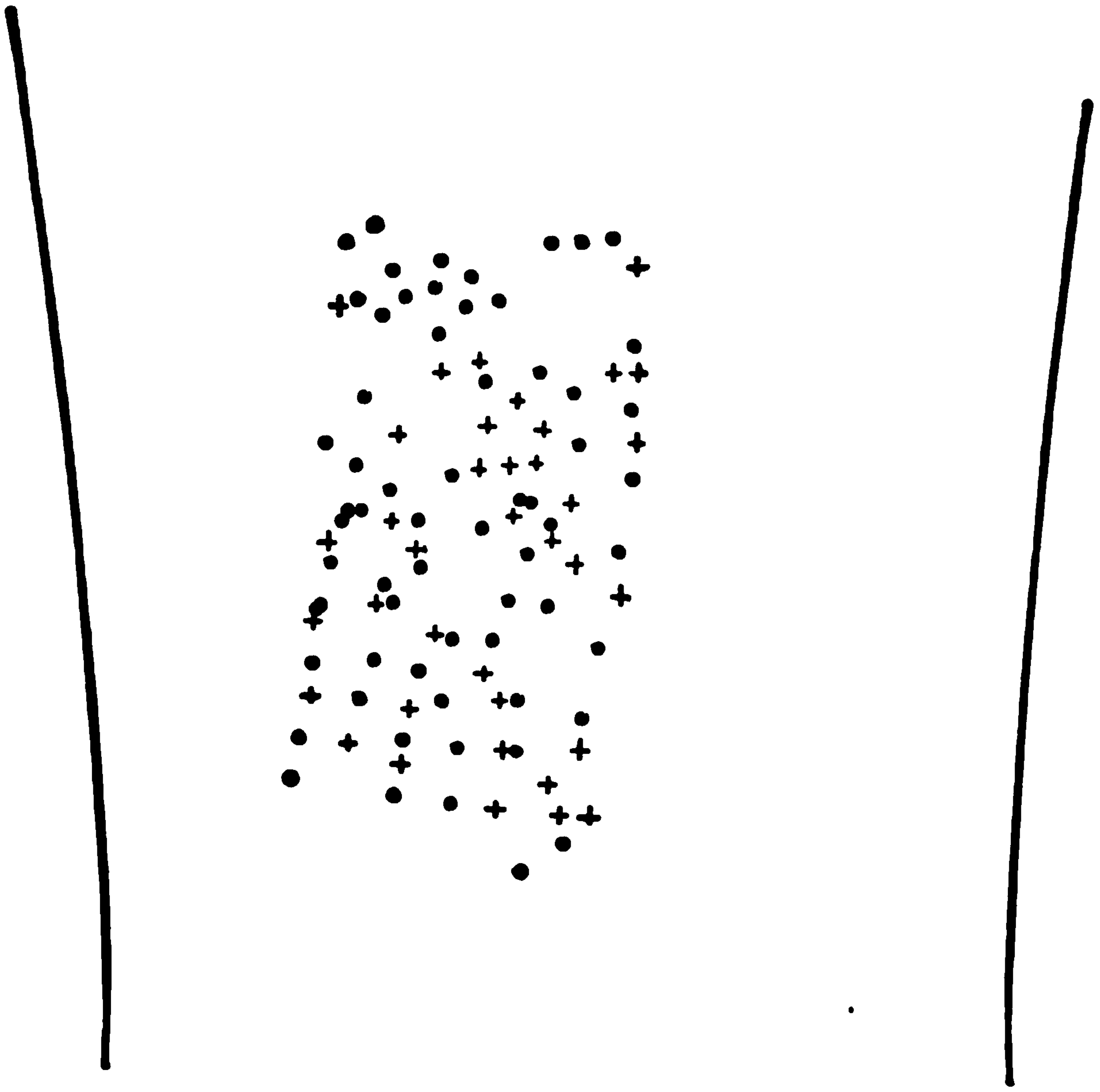

FIG. 56.—Map of temperature spots on volar surface of the forearm. The dots represent warm spots as tested at a temperature of 41–48° C.; the crosses, cold spots tested at 10°. (From Howell after von Frey.)

organ, in very much the same way that his complementary colors depended upon those processes in the single color organ. It was therefore essential when the spots were first mapped to prove by other evidence that the spots were distinct. Certain characteristic differences in the way the two organs respond and in the substances that stimulate them provided this evidence. 1. It takes considerably

longer to stimulate the warm spots than the cold spots, perhaps an evidence that the former are farther from the surface. 2. Certain inadequate stimuli will affect one but not the other. Cold is particularly easy to excite by induction currents, by pressure, or even by heat. Menthol stimulates the cold, carbon dioxide the warm organs. 3. There are certain larger areas of the body in which only one sort of sensation will be found. Thus on the cornea and conjunctiva of the eye cold alone is felt, warmth is lacking altogether. That there are different organs for cold and for warmth is not now disputed.

**The Temperature Scale.** — The more detailed relation between the physical temperature and the sensations that result from the stimulation may be given. The critical point for most purposes is the so-called physiological zero point that separates cold from warm. This point varies much with the temperature to which the skin has been adapted. For a covered part of the body, it is apparently in the neighborhood of from 28° to 30° C.; on the back of the hand, it has been found to vary between 23° and 33°, and after the hand has been immersed in water at 11° for some time, water at 12° seems warm, and it may similarly be adapted for temperatures of 39°. The width of the indifference point seldom is greater than 0.5°. If we assume an indifference point at 30° C., below it the cold spots alone are stimulated to somewhere in the neighborhood of 10°, where pain is added to the complex. Above, one obtains warmth alone up to 45°. Here the cold spots are excited in addition to the warmth, and the combination gives hot as opposed to lukewarm. This excitation of the cold organ by a hot stimulus gives what is known as a paradoxical cold. The fact was first discovered by Alrutz and has been confirmed by von Frey. One experiment performed by Alrutz

was to fatigue the warm spots in the foot by keeping it immersed for some time in warm water and then to swing it quickly through hot water. The hot water then seemed cold. Above 50° to 55° the sensation of burning heat makes its appearance as a consequence of the mixture of pain with

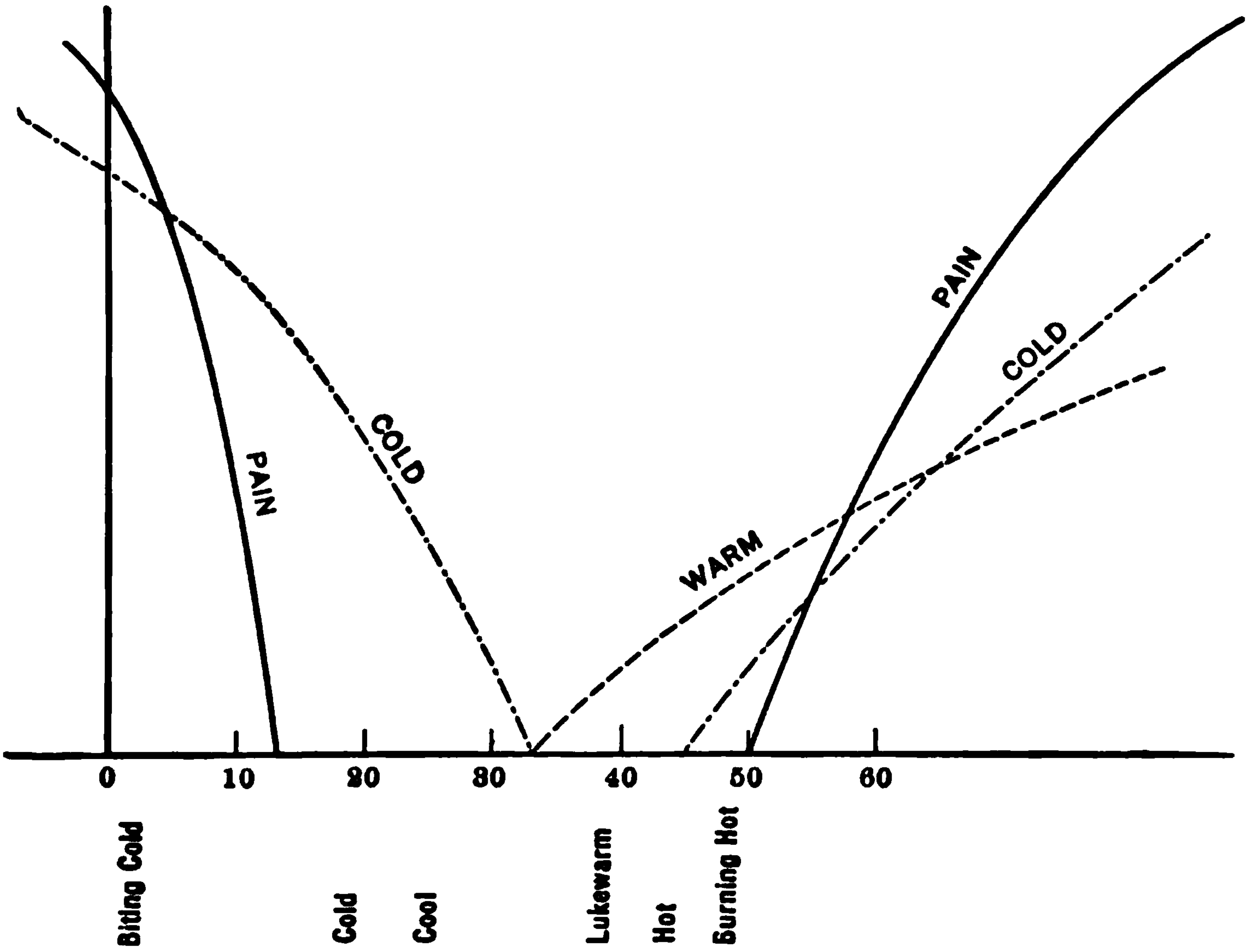


FIG. 57. — Temperature scale. Shows the sense organs stimulated and the degree of stimulation at different temperatures. Figures on the base line indicate the temperature in centigrade, the height, the degree of stimulation. (After von Frey.)

the other sensations. The question naturally arose as to whether there was a paradoxical warmth at the lower ranges similar to the paradoxical cold. The burning sensation after long exposure to cold suggests that the warm spots might be stimulated. Experiments by Alrutz and Thunberg, however, gave no warrant for the assumption. The warm or hot sensations at low temperatures are probably due to the mixture of sensations of pain with some tinglings

due to changes in circulation. Figure 57 shows these various phenomena in diagrammatic form.

### *Pressure and Pain*

**Mechanical Cutaneous Sensations.** — Very much the same distinction may be made between pressure and pain as between warmth and cold. Goldscheider also discovered that only certain points on the body would respond to pressure. There was approximately the same difference of opinion between Goldscheider and the others as to the number of spots. Goldscheider found many, the others relatively few. Von Frey, who has done the most careful and most recent work on the pressure sensations, found that there are from 0 to 300 per square centimetre. On the whole body surface, excluding the head, where they are the most numerous, he estimates there are approximately 500,000. They are more numerous than either kind of temperature spots. In determining their position von Frey used fine hairs mounted on matches or similar small bits of wood. These gave a very small point and a constant pressure. Wherever there were hairs on the body he found that the pressure spots correspond to them. They are also found on the surfaces free from hairs.

**Sensations of Pain.** — Pain has been even more in dispute than the other senses. Until von Frey's[1] work in 1896 it had usually been held either that pain was a feeling, not a sensation at all, or, if it was a sensation, that it must be regarded as due merely to the overstimulation of the pressure organ. Goldscheider in his investigations modified this view slightly. Pain stimuli were carried to the spinal cord by the same neurons as pressure, but there took a different course. While the pressure sensation continued by

[1] Leipziger Abhandlung, 1896

the same neurone up the posterior columns, the intense impressions were supposed to force a way across a synapse to new neurones with cells in the central gray and take another path. As evidence that there is this more difficult path through the central gray, Goldscheider adduces the long time required to receive pain sensations. The reaction time for pressure is from 0.12 to 0.2, while the time for pain rises to 0.6 to 0.8 second. He uses this theory also to explain summation pains such as those involved in the Chinese water torture, in which drops of water are permitted to fall for a long time upon the same point until the successive slight stimuli give rise to an unbearable pain. The summation is assumed to take place in the cells of the cord. Also the effects in the disease syringomyelia are mentioned as confirmatory of his theory. In this disease an infection extends from the central canal, destroying the cells in the surrounding gray matter. Patients suffering from this disease feel only pressure and cold in certain areas of the skin, but have no sensations of pain and warmth. Goldscheider interpreted this to mean that the paths for pain were destroyed, while the paths through the white matter were left intact. Goldscheider, too, explained on this theory the 'referred pains' so prominent in most diseases. He assumes that two or more regions of the body are connected with the same cells in the cord. Thus he would say that the mucous membrane of the stomach and the skin of the back were connected with the same cells in the cord. When certain disturbances of the stomach developed, the excitation of its nerves would be carried to the cells in the cord that give rise to the sensation of pain, and the sensation would be excited in the cortex. But since the same cells also transmit pain impulses from the middle of the back, and we are much more familiar with that area, the pain

would be referred to the known region, the back, rather than to the wall of the stomach, a surface never seen and where voluntary contact has never produced pains. A somewhat similar theory of referred pains has been given by Head[1] without accepting the other portions of Goldscheider's theory.

**Pain Spots.** — More recent investigations have shown that the first part of Goldscheider's theory, that pain and pressure impulses have the same path to the cord, is probably incorrect. Von Frey, in particular, by very careful mapping of the skin, has shown that there are special pain spots in the skin in addition to the pressure and temperature spots. The mapping was on an enlarged scale diagram of the small portion of the skin worked with. The skin was explored with a sharpened horse hair under a magnifying glass, and it was found that sensations of pain were given only at certain points, mostly in the small lines of depression on the skin. These were found to be much less sensitive than the pressure spots, required about one thousand times as great a pressure to stimulate them, and were much more numerous than any other, on the average, one hundred to the square centimetre. It was estimated that there are between two and four million pain spots on the surface of the body. Much corroboratory evidence has been brought to confirm the results of mapping the spots. It has been found that there are some parts of the body, the conjunctiva of the eye, for example, where there are pain spots but no pressure spots; others, as the inner lining of the cheek, where there are pressure spots but no pain spots. Another bit of evidence depends upon the slow response to pain mentioned above. If a pressure spot be stimulated by a slight alternating electric current with alternations of fifty or sixty

[1] Brain, 1893.

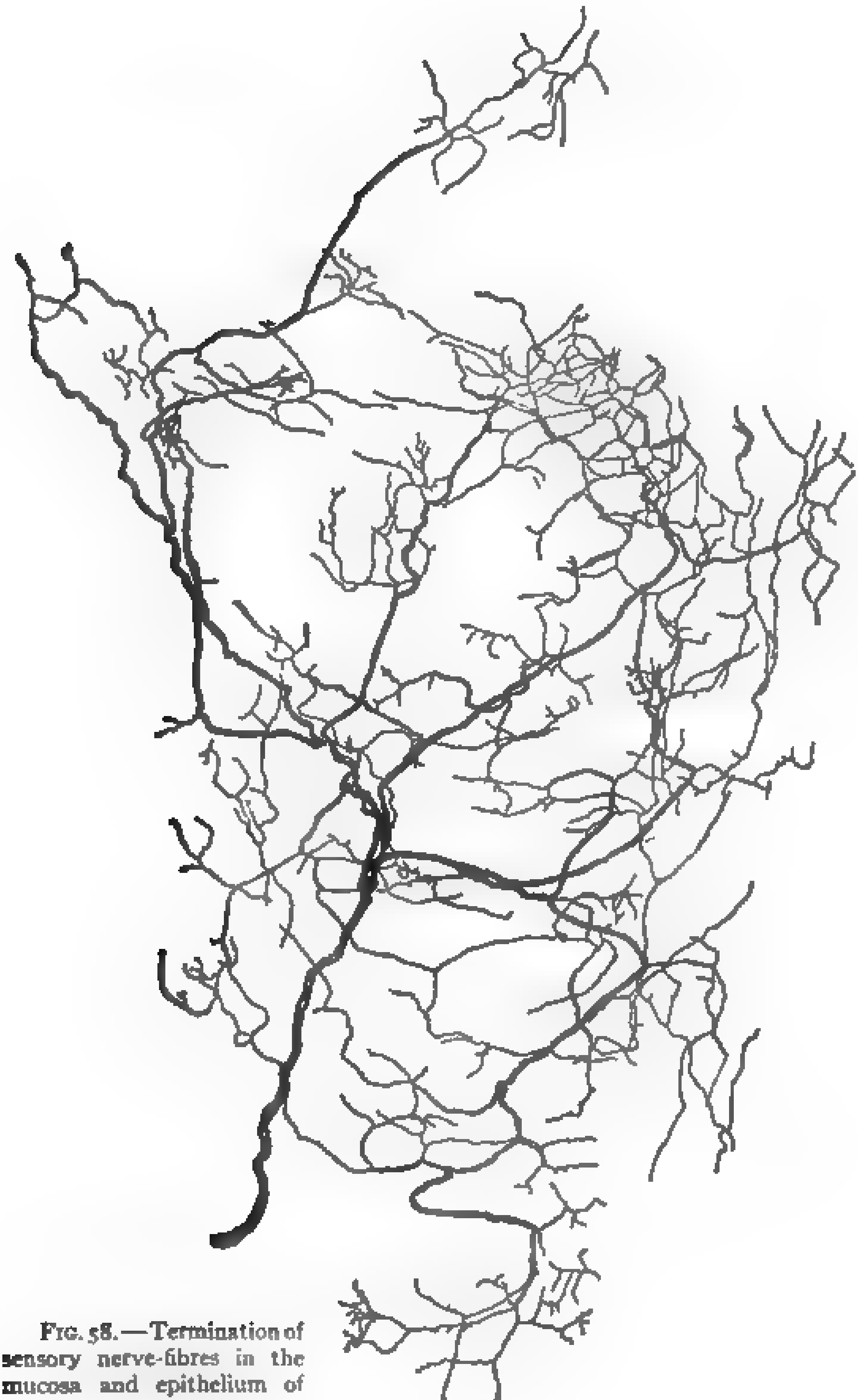

FIG. 58.—Termination of sensory nerve-fibres in the mucosa and epithelium of the cat. (From Huber.)

per second, the separate alternations will be noticed. If, on the contrary, the current be applied to a pain spot, there is a continuous sharp sensation.

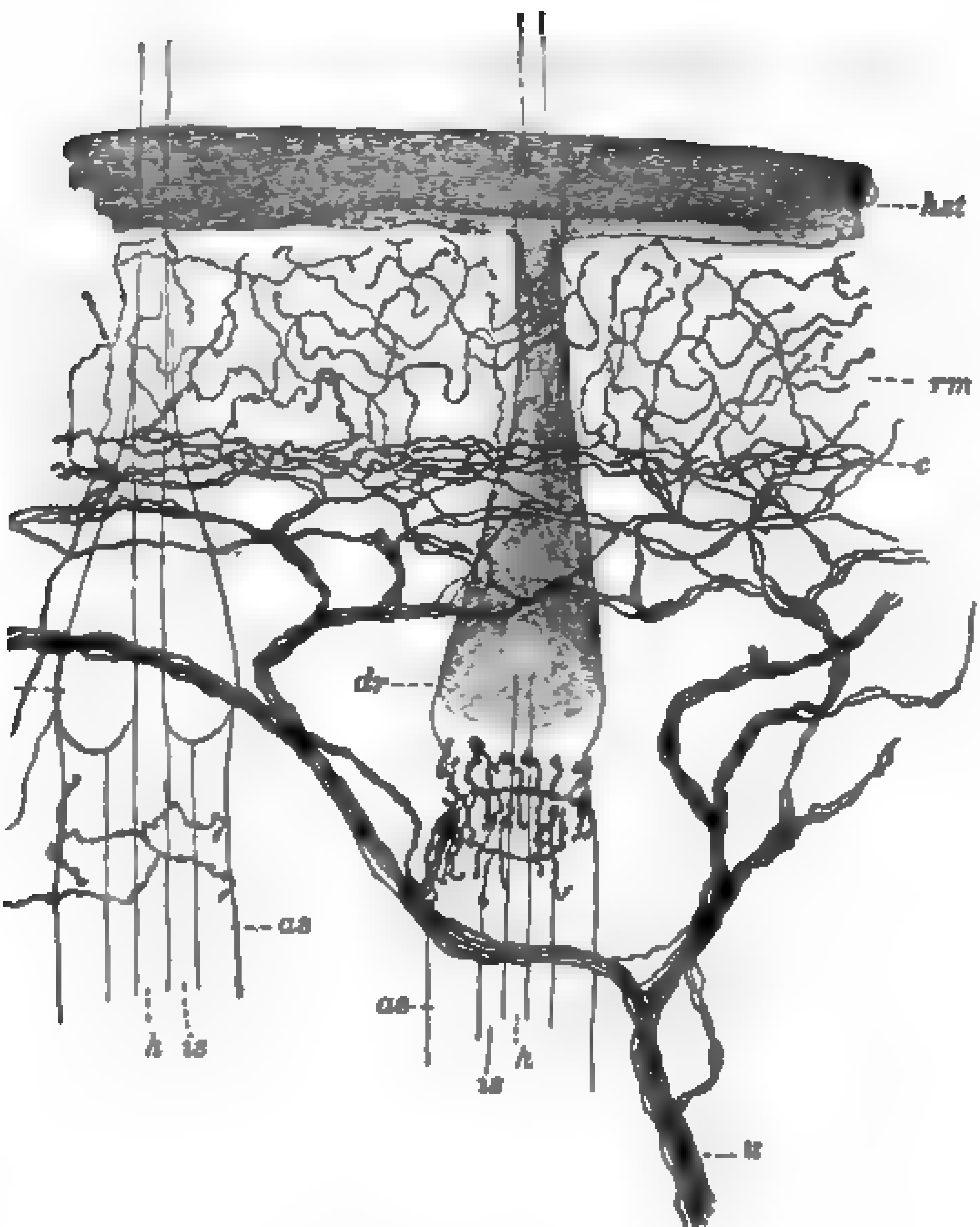


FIG. 59.—Nerve endings in skin and about hair follicles. c, superficial plexus of fibres in skin (free nerve endings are still nearer the surface), h, the hair with nerves about root (From Barker, after Retzius.)

**Cutaneous Sense Organs.** — The sense organs for these different sensations have been determined with varying

degrees of certainty. Pressure spots seem closely connected with the hairs on the parts of the body where there are hairs. The spot that responds is always just over the root of a hair (Fig. 59). It is probable that the nerve about the root is stimulated by the hair which, as it is bent, acts as a lever. On the surfaces without hairs, the palms and soles of the feet, von Frey suggests that the Meissner corpuscle (Fig. 60) is the organ. Pain spots are ascribed to the free nerve endings (Fig. 58). These come closest to the surface of any of the end organs in the skin and the sensations of pain are aroused by the most superficial stimulations. Acids that affect only the epidermis give pain sensations without sensations of pressure or temperature. It is more difficult to determine the organs for temperature and the results are less trustworthy. Following von Frey again, we may regard the end organs of Krause (Fig. 61) as the sense organs of cold, since they with the free nerve endings are the only sense organs found in the conjunctiva, where also only pain and cold can be felt. Because the sensations of warmth seem to originate well below the surface and the organ of Ruffini also is found relatively deep, that has been regarded as the sense organ of warmth (Fig. 62).

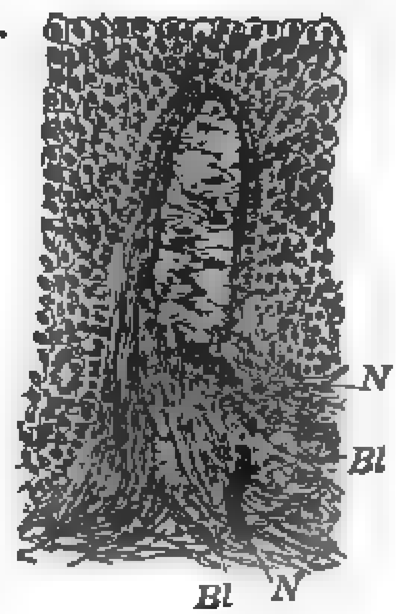

FIG. 60. — Tactile corpuscle of Meissner from the skin of the toe. *N*, nerve fibre. (From Barker.)

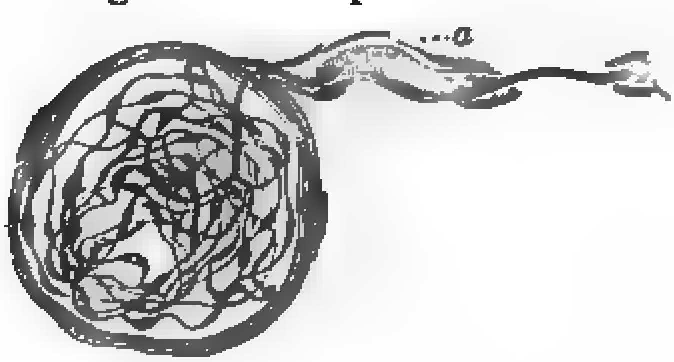

FIG. 61. — End bulb of Krause. (From Barker.)

**Regeneration of Cutaneous Sensations.** — An experiment performed by Head and Rivers tends to establish a second classification of cutaneous sensations that has not been brought into complete agreement with the one given above. They cut the ulnar nerve where it is near the surface at the elbow and then studied the sensations that remained and the gradual reappearance of sensations as the nerve regenerated. At once, after the nerve was cut, all sensations from the skin proper disappeared. Neither pressure nor pain, warmth nor cold, could be felt. When more intense stimulation was applied, pressure and pain could be felt from the tissues under the skin, of approximately the same quality as from the normal deeper tissue in the arm. This they call the deeper lying sensibility. After the lapse of forty-three days, sensations first began to return to the skin. The first evidence of regaining sensation was in the diminution of the area insensitive to pain. On the one hundred twelfth day sensations of cold made their appearance, and the area sensitive to pain had much increased. Nearly two months later the hairs were found to be sensi-

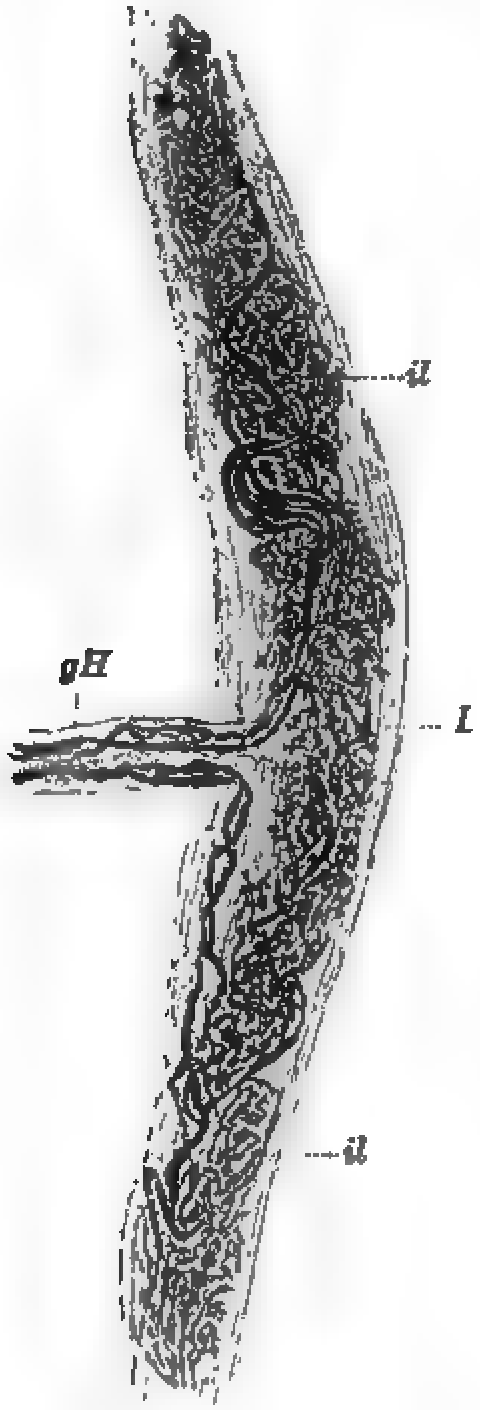


Fig. 62 — End organ of Ruffini. (From Barker.)

tive to light touch and a few warm spots made their appearance. One hundred and ninety days after the operation all of the sense qualities had returned over approximately the entire area. But each of the sensations was limited in some way as compared with the normal. Temperatures below 37° C. and above 27° C. could not be felt at all. Pain sensations could be felt only from unusually intense excitations, and then were exceedingly disagreeable and diffuse, and were generally referred to some point at a distance from the one stimulated. Touch could be felt only on the hairs, — when an area was shaved, no touch was felt. The sensibility producing this condition the investigators call *protopathic*. Curiously enough one small triangle in the affected region was discovered in which all the qualities were present that were lacking from the rest. Temperatures between 27° and 37° C. could be noticed, but none of the extremes. No pain was felt; pricks gave mere sensations of contact and were always correctly localized. Perhaps most remarkable of all, light contact with cotton wool was appreciated on this small triangle from the beginning and was correctly localized whether hairs were or were not stimulated. This more highly developed and more accurate sensibility was known as the *epicritic*. After the lapse of a year, the epicritic sense returned to the entire area. The protopathic sensibility had reappeared in the small triangle with epicritic sensitivity only, one hundred ninety-eight days after the operation. This experiment indicates that three sets of sensory nerves supply any member. One is found in the deep tissues, the two others in the skin. Of the latter one provides the coarser, more intense sensations, the other the more delicate. The protopathic is stimulated only by relatively intense pressure and that only on the hairs; very intense stimuli also give pain. It also is affected by the

extremes of temperature alone. The epicritic sense, on the other hand, supplies the gaps left by this sense; it appreciates moderate temperatures and slight pressures. The relation between the separate spots that have been shown to produce the specific sensations and the epicritic and protopathic sensibilities has not been completely worked out. It seems difficult at first sight to harmonize the two sets of results, and another series of observations on a subject with a regenerating nerve which shall include mapping of the spots at different stages is desirable to complete our knowledge, and to determine how far the two can be made to agree.[1] Later workers, Trotter and Davies,[2] and Boring,[3] have not confirmed these results altogether. They found a gradual return of each sense, — pain, pressure, and cold returning together, and warmth considerably later.

### Sensations of Taste

**Gustatory Sensations.** — While tactual sensations have been found much more numerous than was thought as knowledge about them increases, sensations of taste have been diminished in number quite as definitely and markedly. The popular mind to-day and the scientific opinion of one hundred years ago assumes that there are a very large number of taste qualities. Even after experiments had been made, it was generally believed that at least six could be distinguished. The older list included nauseating tastes, aromatic, and other qualities that we now know to be derived from smell. Chevreul showed in 1824 that these

[1] Rivers and Head, A Human Experiment in Nerve Division, Brain, xxxi, 323.

[2] Trotter and Davies, Experimental Studies in the Innervation of the Skin. Journal of Physiology, Vol. XXXVIII, 1909, pp. 109, 134 ff.

[3] Boring, Cutaneous Sensation after Nerve Division. Quarterly Journal of Experimental Physiology, Vol. X, pp. 1–96.

must be smell qualities by his discovery that they disappeared upon closing the nostrils. Until relatively recently salt, sweet, sour, bitter, metallic, and alkaline were regarded as the primary tastes. The metallic seems on closer experimentation to be a compound of taste with smell and with mechanical and perhaps muscular sensations. The metallic surface may produce slight muscular contractions in the

Fig. 63. — Fungiform papilla from human tongue. (From Huber.)

neighborhood of contact which add to the other taste and smell sensations to produce a complex. Alkalies if strong may make the tongue slippery and may also produce puckering of the surface of the tongue. Von Frey has shown by closing the nostrils while tasting that alkalies also contain odors. When the tongue is at rest and the nose closed, the only sensation is a slight bitterness. Eliminating all sensations of smell, which furnish a large part of what is called taste in gastronomic relations, and all tactual and tempera-

ture sensations, such as the biting of spices, etc., we have left only four true tastes, — sweet, salt, sour, and bitter.

**Sense Organs of Taste.** — The problem of the organ of taste, and its specific type of reaction, is similar to the same problem on the skin, but slightly more complicated. The

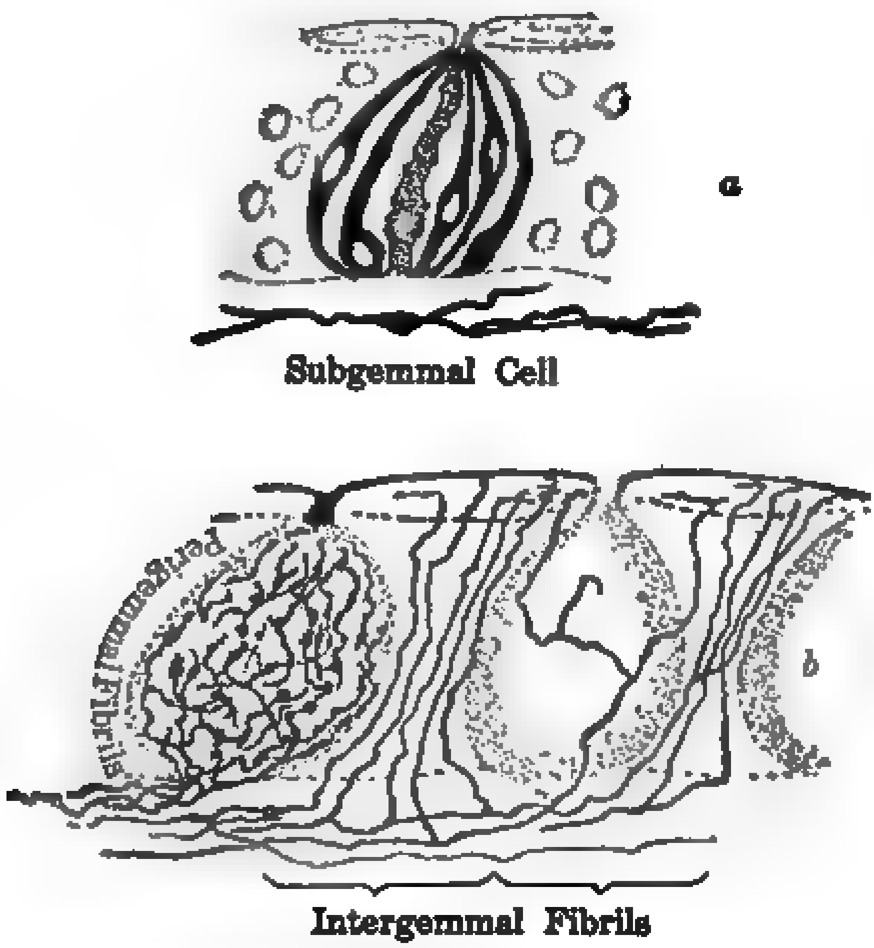


FIG. 64. — Taste buds and endings of gustatory nerve; *a* shows taste cells about a central supporting cell; *b*, fibrils around and between the taste buds. (From Barker.)

sense endings of taste are found primarily upon the tongue, but also in some numbers upon the soft palate, upon the cords of the larynx, the epiglottis, and in children on the inner lining of the cheek. On the tongue the end-organs are the papillæ. These are elevations set deep in the mucosa. The sense ends are on the sides of the resulting folds. The most striking are the circumvallate papillæ, from seven

to twelve circular depressions, much like the moat of a walled town, arranged in an angle upon the back of the tongue. The most numerous type in man are the fungiform, whose small red openings may be seen upon the tip of the tongue. In some human beings the foliate papillæ are present and have sense organs. They are very prominent in animals. The real sense ending is the *taste bud* or beaker. These are collections of taste cells and supporting cells arranged in the form of a bud. The taste cells have hairs on their ends that extend into the papillæ where they come into contact with the saliva in which the chemical substance that gives rise to the taste has been dissolved. Around the taste cells are nerve fibrils bare of their medullary sheaths. The function of the papillæ is apparently to catch the saliva and permit it to come into contact with the taste cells, and there to start the nervous impulse.

**Doctrine of Specific Energies for Taste.** — Much discussion has been devoted to the question whether a single taste bud in a papilla can give rise to one only or to more than one sensation. Experiments performed by Oehrwall of stimulating the papillæ separately showed that more than one sensation might be received through a single papilla. He mapped accurately 125 papillæ and then stimulated each separately with solutions of sugar, quinine, and tartaric acid. Of these, 27 gave no response at all, 60 responded to all three substances, 12 gave acid only, 3 sweet only, none bitter only, 4 gave sweet and bitter, 12 sweet and acid, 7 acid and bitter. From this experiment, which has been repeated by several investigators with approximately the same result, it is evident that the papillæ cannot be regarded as the organs of different special sense qualities as are the spots on the skin. It is suggested by the supporters of the doctrine of specific energies that the immediate sense

end is the taste bud and that, as there are always many of these in each papilla, it is possible that each taste corresponds to a particular sort of nerve end, but that several different kinds are found in each papilla. As the separate beakers cannot be stimulated individually, this assumption cannot be confirmed directly. Some indirect evidence in its favor is offered by the fact that on the application of certain drugs the tastes disappear one at a time, presumably due to the fact that the primary end organs are affected with different ease. Thus, cocaine applied to the tongue destroys first the sensation of bitter, and the others in succession, while gymnemic acid first destroys the sensation sweet. Similarly, the distribution of the taste sensitivity on the tongue tends to confirm the same theory. Bitter is most prominent on the back of the tongue, — in some individuals is confined to that region; sweet is more pronounced on the tip, sour on the sides, while salt is more generally distributed. The distribution varies from individual to individual. In some, bitter will be lacking altogether on the tip, while in others it is present, but in few papillæ. A similar statement may be made for each of the taste qualities. As further evidence that there are specific endings for each quality, the same substance will produce a different taste as it is applied to one part of the tongue or the other: sodium sulphate has a sweet taste on the tip, a bitter taste on the back of the tongue, a difference that must be due to the organ stimulated. Similarly, pressure or electrical stimulation of the chorda tympani, one of the nerves of taste, where it passes through the middle ear, may produce sensations of taste. Still another bit of evidence for the independence of the organs for the different tastes is difference in the time required for stimulation. On the tip of the tongue salt requires from 0.25–0.72 second to be appre-

ciated, sweet, 0.30–0.85, sour, 0.64–0.70, bitter, 1–2 seconds. The longer time for bitter is especially striking. While the doctrine of specific energies is not open to direct test, the indirect evidence, so far as it exists, supports the hypothesis.

Attempts have been made to discover some relation between the chemical composition of substances and their tastes. As is well known, acids are sour so generally that the two words are popularly synonymous as applied to taste, and in German are designated by the same word. There are, however, many exceptions on both sides. For the other qualities the lack of relation between the chemical composition and taste is striking. The more familiar sweets are carbohydrates, but lead acetate, salts of the other heavy metals, and even some alkalies have sweet as one of the component tastes. Much the same statement may be made of the bitter substances. Usually they have a complex molecule, and the more complex, the more bitter, but no more accurate law has been developed. The simple salts are usually more or less salt, but there are many exceptions. In general, the attempts to correlate taste and chemical composition have led to no noteworthy results.

**Taste Fusions and Taste Contrasts.** — The taste qualities show some of the interrelations found in vision. Tastes mix with each other, with the cutaneous sensitivities, and with odors to produce complexes that are not readily analyzable. The statements hold less for taste alone than for mixtures with the cutaneous and olfactory senses. It seems that sweet and sour, sweet and bitter, combine in foods to advantage. Salt and sweet have approximately the relation of complementary colors. When mixed in weak solutions, Kiesow found that they nullify each other. Also when applied to neighboring areas of the tongue, they reënforce

each other, that is, show contrast effects. Thus if one pour upon one side of the tongue a solution of sugar too weak to be tasted alone, and upon the other a salt solution, the sweet will be noticed. Even distilled water may by the same means be given a sweet taste. Other tastes, as sweet and bitter, applied to opposite sides of the tongue, when intense, may alternate; first one appears, then the other, a process resembling binocular rivalry of colors.

The nerves of taste offer some complication. According to Zander, there are three nerves of taste and one of cutaneous sensibility. Of the true taste nerves, the glossopharyngeal, the ninth, supplies the back portion of the tongue; the vagus supplies the taste buds of the larynx and epiglottis and a small area on the very back of the tongue; while the chorda tympani carries the sensations from the forward areas. The chorda tympani enters the tongue as a part of the lingualis, the other portion of which is a branch of the trigeminus, and is the nerve of cutaneous sensibility. In its midcourse it is alone, and then enters the brain stem as part of the intermediate nerve.

## Sensations of Smell

**Olfactory Sensations.** — The organ for smell is situated in a narrow cleft at the very top of the nasal cavity, just under the olfactory lobe at the base of the brain. The olfactory area is marked by a brown pigment which extends over the upper portion of the septum and the roof of the olfactory fissure. The olfactory area is much smaller in man than in animals that make more use of the olfactory sense. The olfactory fissure is above the direct respiratory path — only eddies of the air inspired or expired reach it. This is a protective measure, as dust and other harmful

impurities are largely prevented from affecting the endings. The end organ proper is found in the *olfactory cells*, true nerve-cells, which here alone reach the outer surface of the body (Fig. 65). These cells end in hairs that project slightly from the surface. The axones of the cells pass upwards through numerous openings in the skull to make connections in the

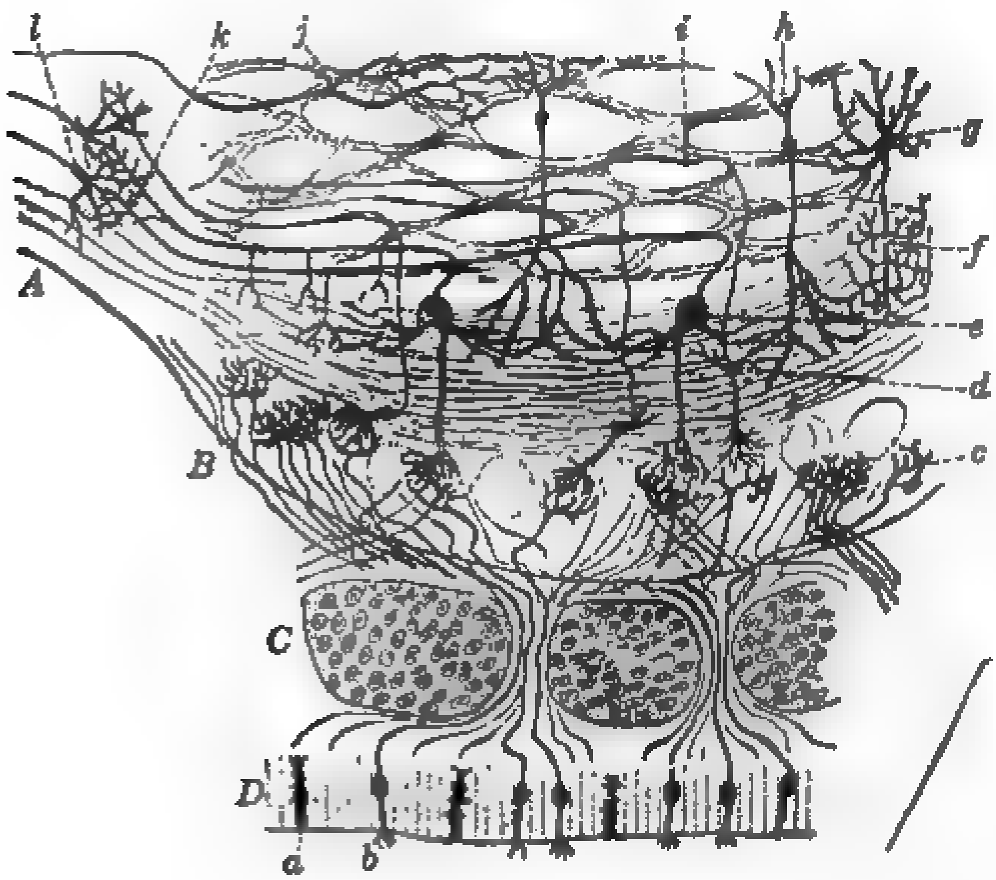


FIG. 65.—Olfactory apparatus. *D*, the olfactory membrane and endings; *B*, glomeruli where end-brush of olfactory neurones connects with dendrite of the more central neurones. (From Barker, after Ramon y Cajal.)

glomeruli with neurones of the olfactory lobe, and thence to connect with the cortical areas for smell. Between the olfactory cells are supporting cells. The chemical substance that gives rise to the odor is carried in the inspired or expired air and comes into direct contact with the hairs of the olfactory cells, where we may assume that the chemical reaction excites the nervous impulse.

**Olfactory Qualities.** — How many sensations of smell there are is still a moot question. The organ is so situated that no direct experiment may be made upon it, and the indirect experiments either have not been carried far enough or are inaccurate. Aronsohn long ago attempted to determine the number by a fatigue method. His theory assumed that one might tire the organ by smelling some one substance, rosewater, for example, until that substance could no longer be detected, and then while the fatigue persisted, test the odors of different substances. Any that could still be detected would belong to some other class, must be sensed through some other organ; those that could not be distinguished would belong to the same class. The method has been proved to be practical, but the large number of substances to be tested and the difficulty in knowing whether the organ is still fatigued for the standard odor have prevented its extensive application. Other evidence of the existence of separate olfactory organs is furnished by pathology. In some diseases of the olfactory region, appreciation of certain odors will be lost while others will still be noticed. But the observations have not been carried far enough to give an accurate classification.

Henning[1] has recently made a classification of odors by questioning men who had special skill in discriminating them. His conclusion is that we may distinguish six primary qualities with a series between each that partakes of the qualities of the two extremes. These fundamental odors are the spice odors, flower odors, fruit odors, resinous or balsam odors, foul odors, and burning odors. Instances of the first class are fennel, cloves, sassafras oil. Included in the flower or fragrant odors are heliotrope, oil of jasmin,

[1] H. Henning, Der Geruch. Zeitschrift f. Psychologie, vol. 73, p. 161, vol. 74, pp. 203, 305.

and oil of geranium. The fruit odors include the fruits proper, oil of citronella and ethyl ether. The resinous or balsam combinations include turpentine, oil of eucalyptus and oil of cedar, as well as the true resins. The foul odors are typified by hydrogen sulphide and other sulphur compounds in addition to bad cheese and similar disagreeable odors of organic origin. The burning odors are typified by smoke, minus the burning sensation, pyridin, and tar.

Henning arranges these odors on a prism with the primary odors at the corners and the intermediate ones on the lines joining them. Typical intermediates between fruit and foul are dill, leek, celery, onion, oil of mustard, and foul cheese; between the burning and spicy lies browning coffee; between burning and resinous, burning varnish. The primary odors of Henning correspond very closely with many of the older classifications. The principal difference is that he omits a number included by the older men which are compounds of smell with pain and other senses. His results can be readily tested and on the whole confirmed.

These qualities mix with the cutaneous sensations from the mucous membranes of the nose, — one quality of smoke, for example, is the same from the eyes as from the nose, — and with tastes. We usually do not distinguish the different components: if the complex comes from food in the mouth, we call the whole a taste; if from the air outside, we call the whole an odor.

Attempts have been made to connect the qualities of smell with the chemical composition of substances. In general it may be said that most odorous substances are found in the fifth, sixth, and seventh groups in the system of Mendeleeff. Haycraft has also shown that in many cases the intensity of the smell in a group increases fairly regularly with the complexity of the molecule. There are

exceptions to these rules and no complete formulation may be made of them. It is probable that the chemical substance is borne on the inhaled and in less degree by the exhaled air to the olfactory nerves and there by direct chemical action arouses the nervous excitation.

**Mixtures and Compensations of Odors.** — Mixtures and compensations of smells can be demonstrated. For these, as for making all quantitative tests of odors, Zwaardemaaker made use of an instrument he called the olfactometer. In essentials it consists of one tube with a curved end to be inserted in the nostrils, and of a second tube of larger size containing an inner lining of the substance to be investigated which slips over the former. The amount of stimulation is measured by the area of the outer tube exposed beyond the inner. If they are even, the air entering the inner tube absorbs none of the substance on the outer; and the more the outer projects beyond the inner, the more saturated with particles is the air that enters the nostril. In the double olfactometer of this sort a tube is applied to each nostril. It is found that if certain substances, Peru balsam and iodoform, for example, are applied either to the same or different nostrils at the same time, they cancel each other and no odor is sensed. Other substances produce mixed odors that may or may not be analyzed into their components. Xylol and turpentine fuse to form a new odor and many others can be mentioned. Certain of these mixed odors are given off by simple substances, as can be shown

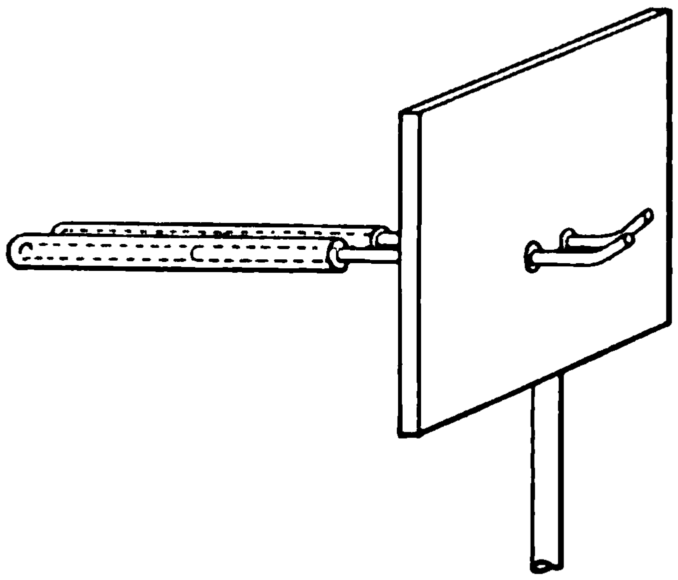

Fig. 66. — Zwaardemaaker's olfactometer. (From Titchener.)

by the fatigue test. Thus if propionic acid be smelled for some time, the original odor will lose one of its components and assume a different quality.

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## KINÆSTHETIC SENSATIONS

**Kinæsthetic Sensations.** — To these traditional five senses of man, modern science has added a number of others. One of the most important is the kinæsthetic, the sense by which we appreciate the movements of our own members. The muscle sense had a prominent place in the English psychology of the last century, — Thomas Brown and the Mills made use of it, -- but the first experimental work of importance on the subject was carried on by Goldscheider in the late eighties of the last century. Goldscheider adduced evidence that the more delicate sensitivity to movement was in the joints rather than in the muscles, as had been earlier supposed. His main bit of evidence for this was that the sensation of movement is markedly diminished if an induction current is passed through the joint as the member is bent. Evidently there are three possible sources of sensation for movement, the external skin, which must be wrinkled at the joint as it bends, the muscles and tendons which are known to be well supplied with sensory endings, and the joint. Goldscheider assumed on the basis of his experiments that the joint surfaces were the organs in spite of the fact that there are known to be no sensory nerves ending on the joint surface, and that an

experiment that he made himself indicated that the membrane on the joint, the synovial membrane, had a very slight sensitivity.

By anæsthetizing these various sources of sensation one after another, it is possible to determine their order of importance in making known the movements. Experiments are made by placing the member to be tested, usually the forearm, on a hinged board, with the joint over the hinge, and then raising the board until the movement is first noticed. The least movement of the arm which can be appreciated is about half a degree. If the external skin be anæsthetized, this will not be changed. The skin, then, must be less important than the internal sense organs. Goldscheider found that if an induction current be passed through the joint, there must be a considerable increase in the movement before a sensation is produced. He regarded this as evidence that the joints were essentially the organs of movement. The writer repeated the experiments and found that although when the elbow or knee joint was anæsthetized by passing an induction current through it the sensitivity for movement was reduced, it was also reduced quite as much when an induction current was passed through the wrist or ankle joint, or the muscles near them, and still more reduced when passed through both at the same time.[1] From this it seems that the essential organs in the appreciation of movement are the muscles and tendons with the sensory nerve ends that are embedded in them. These results have recently been confirmed by von Frey[2] although he would ascribe an important part

[1] Pillsbury, Does the Sensation of Movement Originate in the Joint? Amer. Journ. of Psychology, 1901. Pp. 346–353.

[2] Von Frey, Studien über den Kraftsinn. Zeitschr. f. Biologie, vol. 68, pp. 349–350.

to the tactual sensations. This hypothesis is strengthened by the histological evidence that the joint surfaces are bare of sense organs, and by the fact that careful observation indicates that the movement of the elbow is ordinarily felt either in the wrist or fingers. Instead, then, of regarding the kinæsthetic impressions as coming primarily from rubbing of joint surfaces, we may regard the excitation of the sensory endings in the muscles and tendons by the contraction of the muscle or the stretching of the tendon as the source of our sensations of movement. To this may be added as a subsidiary factor the wrinkling of the joint capsule, which also contains sensory endings.

These kinæsthetic impressions play a very large part in our mental life. It is of course important to know where the different members of the body are at any moment. In addition to this the kinæsthetic sensations contribute very largely to the coloring of other experiences; they guide the different movements and constitute an important element in the emotions. We shall have occasion to make use of them often in the later chapters.

## The Sense of Equilibrium

**The Static Sense.** — Closely related to the kinæsthetic sense in function is the sense of equilibrium. This is also a sense of relatively recent discovery. In 1872 Crum Brown, Breuer, and Mach independently reached the conclusion that the portion of the inner ear not used in hearing, the so-called vestibular portion of the ear, is closely connected with keeping the balance, and with the appreciation of the movements of the body as a whole. The evidence accumulated since is altogether convincing. The organs involved are the sacculus, the utriculus, and the semicircular canals, named in order from the vestibule. The sacculus is a mem-

branous sack floating in the lymph contained in an enlargement of the bony labyrinth. This opening communicates with the vestibule, and the lymph is continuous with the lymph of the cochlea. A branch of the vestibular nerve enters the sacculus, and ends in hair cells. Among the hairs are small crystals of calcium carbonate, the otoliths. The utriculus is a similar, somewhat larger sack connected with the sacculus by a small opening. The nerve endings are

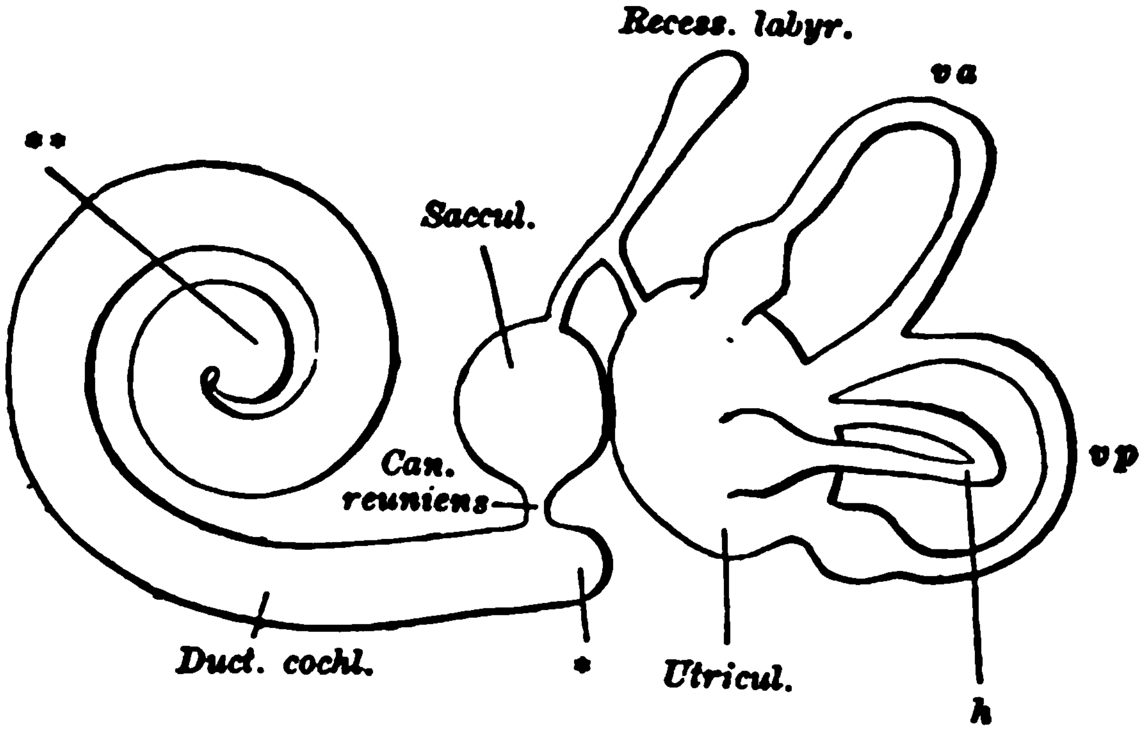


FIG. 67. — The left membranous labyrinth of the ear seen from without. *va*, *vp*, the anterior and posterior semicircular canals; *h*, the horizontal canal. The relation of the sacculus and utriculus to the cochlea is also shown.

similar to those of the sacculus. From the utriculus extend the semicircular canals, one in each plane of space. They have two openings into the utriculus, making possible a movement of the lymph through the complete semicircle. Near one opening of each canal into the utriculus are small swellings, the ampullæ. In these end the branches of the vestibular nerve that go to each canal. The nerves end in long hairs that protrude into the lymph of the ampullæ. The different branches of the vestibular nerve unite with each other and join the cochlear branch to constitute the eighth nerve. In the brain stem the two branches have

separate nuclei. The nucleus of the vestibular branch has connections primarily with the cerebellum and with the nuclei of the motor nerves of the eye.

The evidence that the function of these organs is primarily to keep the balance is now manifold. The earlier investigators proved that sectioning a semicircular canal in a pigeon disturbed its balance and the tonus of its muscles, and at first made it stand with the head drawn to one side. It was also shown that passing a strong electric current through the ears would produce a turning of the head. Studies of patients with diseased vestibular organs showed characteristic loss of some one function according to the part affected and the length of time the disease had lasted. Many of the deaf are also defective in keeping the equilibrium. If one registers the movements they make when standing erect with eyes closed, it is found that they sway much more than the normal

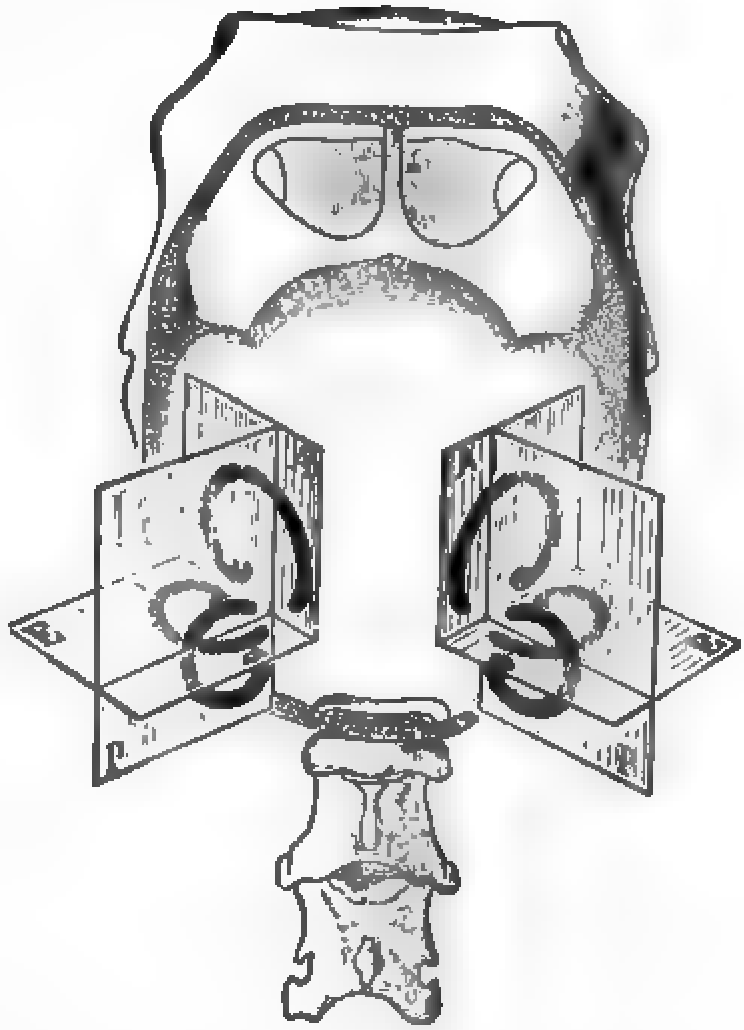

FIG. 68. — Shows the arrangement of the semicircular canals of the pigeon, looking from behind into the opened skull. In plane *A* is the anterior semicircular canal; in plane *P*, the posterior; and in plane *E*, the horizontal of Fig. 67.

individual. It is also found that about half the deaf do not have the compensating eye movements, that is, the movements of the eyes that make the eyes turn in the direction opposed to that taken by the head, that permit the eyes to fixate a point reflexly in spite of movements of head or body. In many cases the vestibular portion of the ear is normal when the cochlea is affected.

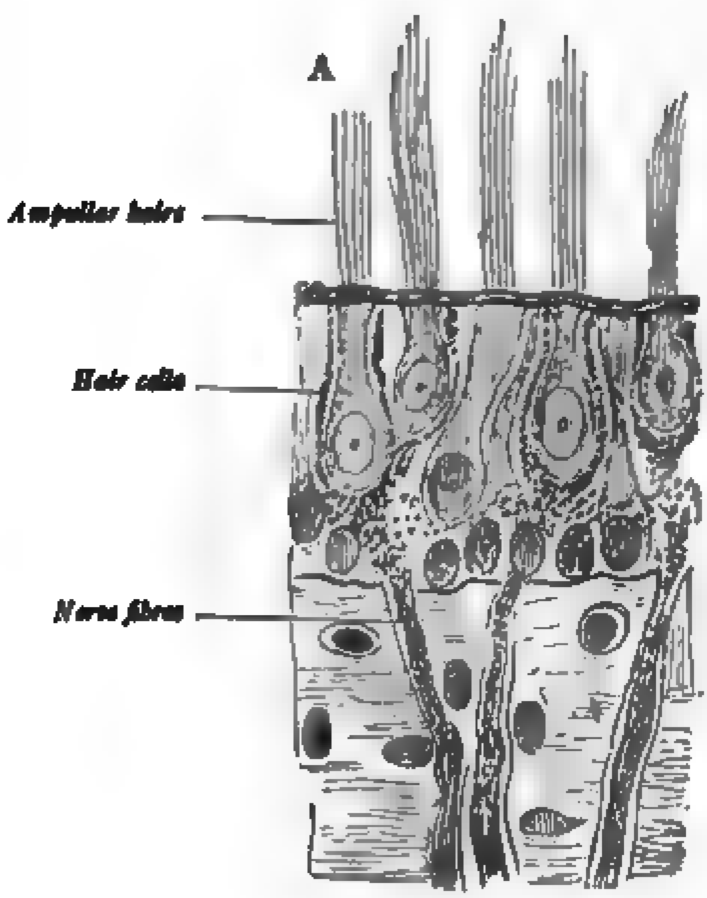


FIG. 69. — The hair cells and the hairs that protrude from the ampullæ of the semicircular canals into the liquid. Movement of the liquid displaces the hairs and stimulates the nerve cell.

Streeter has shown that if he destroys the vestibular region in the tadpole, the frog that develops from it has no sense of position, is as likely to swim on its back or side as right side up. Kreidl inserted iron filings in the otocysts of the crayfish when they were opened by the shedding of the shell, in place of the particles of sand that normally find their way into the cavities at that time. After the new shell was grown he found that if he brought a magnet over the crayfish they would at once turn and swim on their backs. Evidently the attraction of gravitation for the sand particles had been replaced by the magnetic

[1] Streeter, Journal of Experimental Zoölogy, vol. iii, p. 543.

attraction for the iron filings. These various lines of experimental evidence, together with the probability raised by the close central connection of the nerve with the cerebellum and with oculomotor centres, are conclusive proof that the vestibule contains the organ for the static sense, and is the source of reflexes for many eye movements and for keeping the balance, as well as for keeping the general tonus of the muscles.

**The Organs of Equilibration and their Stimuli.** — The mechanism of the stimulation of the sense organs may be made out in a measure from the experimental data and the structure of the organs. Movements of the body as a whole probably stimulate the sacculus and utriculus primarily. As the body moves forward, the otoliths are left behind for a moment through their own inertia and so move the hairs and stimulate the nerves. This excitation occurs only at the start; soon the otoliths take on the motion of the body and no further excitation occurs. The opposite stimulation is given as the motion ceases; the otoliths continue to move forward under their own inertia for a time and produce the same effect as if the person were starting backward. This may be noticed as a train comes to a stop. For an instant one seems to be starting backwards. Going up or down, as in an elevator, also displaces the otoliths and gives the corresponding sensations. Movements of rotation and of turning the head in the different planes affect the semicircular canals. The hairs in the ampullæ are probably stimulated by the movements of the liquid and these stimulate the corresponding nerves.

It is a question whether these excitations give rise to a sensation of their own or whether they merely excite reflexes and these reflexes are appreciated. Violent excitations produce sensations of giddiness and finally nausea and vom-

iting, as in seasickness. Slighter excitations only call out movements of the eyes and the movements required to keep the balance. The same sensations of giddiness and even nausea may be produced by rapid irregular movements of the eyes without movements of the body. All of this speaks for the view that the sensation of giddiness is not a true sensation of the vestibular nerve, but rather a sensation from the alimentary canal, due to reflexes excited by the organs of equilibrium. On this theory the vestibular nerve excites no peculiar sensation, but serves to adjust the different muscles of the body, including primarily the eye muscles, to the various movements of the body. The sensations arise from the reflexes when they become intense. It should be noted that visual sensations, kinæsthetic sensations, and sensations due to displacement of the large visceral organs also aid in keeping the balance and in appreciating the movements of the body. The deaf who have lost the sensitivity of the vestibule can, by means of these other organs, still retain the balance, though less accurately.

## Organic Sensations

**Hunger and Thirst, General Sensibility.** — Of the sensations from the inner organs, hunger and thirst probably bulk largest in the daily life of man. Hunger has been recently investigated by Carlson and by Cannon.[1] They find in man and dogs that it is a comparatively transient accompaniment of the deprivation of food. During a period from three to five days after food is stopped, the sensations become continually weaker and gradually practically disappear. They are, however, rearoused by sight of food or by anything that suggests food. The sensations were found to be due to contractions of the walls of the

[1] Cannon, The Physiological Processes in Pain, Hunger, Fear, and Rage.

stomach. Records of these contractions were taken by swallowing a rubber sack or balloon with tube attached which could be inflated to fill the stomach, and then registering, upon a revolving drum, the compressions of the air in the balloon. These contractions are particularly vigorous when hunger is keenest, and in general run parallel to the sensations. Thirst has its seat in the back of the throat. It is apparently due to the drying of the membrane there. It may be relieved by laving the back of the mouth with citric acid or by taking liquid into the system, either through the mouth, through an artificial opening into the stomach, or directly into the circulation. Each of these processes leads to the moistening of the membrane in question. In addition to the qualities of sensation discussed, there are a vast number of other sensations which fuse in the general complex of organic sensibility. It is useless to speculate upon their quality or their number. With the advance of science others will undoubtedly be separated from the mass and be recognized as separate senses; some already have names ascribed to them in popular speech. Of these, the more external, of tickling, pins and needles, itching, have been explained in different ways; pins and needles by changes in circulation; tickling by contractions in the skin muscles, survivals of the fully developed skin muscles in animals, or, by certain authors, as due to stimulation of tickle spots, a fifth form of sensory spot in the skin. No one of the explanations can be regarded as more than hypothetical. The internal sensations are even less known and few if any distinctive names can be given. Such names as are given refer to particular complexes, such as those present in the different emotions, rather than to specific sensations. Some of these inner sensations are of the same quality as the cutaneous sensations, and are always fused

with sensations from the contraction of various muscles. They are most frequently fused into the vague feelings of well-being or ill-being, and are attended to only as signs of health or of general bodily state.

### The Doctrine of Specific Energies

**The Doctrine of Specific Energies.** — A final problem is the bearing of the results so far discussed upon the doctrine of specific energies. We have found that law convenient as an introduction to the study of sensation, and have used it as a guide throughout. But it is now time to determine how accurately our hypothesis harmonizes with the facts. The doctrine for convenience may be divided into different parts. 1. A nerve end when stimulated at all always gives rise to its own peculiar sensation. 2. There are as many nerve ends as there are specifically different sensations. 3. The quality of the sensation depends upon the character of the end organ rather than upon the nature of the stimulus.

If we examine these phases of the doctrine one by one, we find that the first holds so far as it is possible to test it at all accurately. It applies to the retina, to the end organs on the skin and on the tongue, less certainly to the olfactory organ. In discussing the problem we distinguish adequate from inadequate stimuli. An adequate stimulus is one that excites the organ in greatest perfection. Light is an adequate stimulus for the eye, sound waves for the ear, etc. Adequate stimuli give the full number of sense qualities of which the organ is capable. Other stimuli are inadequate. The electric current is an inadequate stimulus for all senses, pressure an inadequate stimulus for the eye, etc. Each of the sense organs mentioned may be excited by one or more inadequate stimuli, and when excited responds with

a sensation of the quality peculiar to that sense. The number of stimuli that will excite the organ and the intensity of stimulation required vary from organ to organ and for the different sense qualities within the same organ. The sensation that arises when the organ is stimulated also shows various degrees of approximation to those excited by the adequate stimulus. On the skin, most of the organs may be excited by several stimuli and give approximately the same quality as that produced by the adequate stimulation. The olfactory endings are excited with difficulty and then, so far as is known, only by electrical stimuli, and the resulting quality is very uncertain. The location of the organ may account in part for the uncertainty of the result. The retina has an intermediate position in both respects. Mechanical and electrical stimuli at least will affect it, and they produce several sensory responses, but not the variety or delicacy of effect produced by the light waves. While the law will not hold with the completeness that a firm believer might wish, still it can be said in general that sense organs may be affected by various stimuli, and when they respond, *if they respond at all*, the quality is that ordinarily given by that organ rather than the quality produced by the stimulus in the organ for which it is the adequate stimulus.

The second law is less definitely demonstrable. Except on the skin, one cannot prove that each sense quality has a separate nerve end. From what we know of the eye, the cones probably have more than one sense quality, and while one might assume that there are different chemical substances in each cone, it is hardly likely that there are different nerve ends. A case might be made out for separate taste buds for each quality; there is slight evidence for separate organs for each odor. In hearing, the Helmholtz

theory depends for its truth upon the law rather than substantiates it. Strictly, then, the statement that there are as many qualities as there are sense organs and no more holds only for certain senses, and is to be regarded rather as a convenient guide to the discussion of sensation than as a fully substantiated fact.

The third principle, that the quality of sensation depends upon the sense organ excited rather than upon the stimulus, holds approximately. Adequate stimuli excite the organ at a slighter intensity and give a richer quality in most of the sense organs. Nevertheless if one were to decide between the receiving organ or the external stimulus as the determinant of the sensory quality, the receiving organ must be given the more important part.

There is also a question whether, granted that the sensations depend upon the specific characteristics of the nervous system, the determinants of the quality are to be found in the sense organ or more centrally in the nerves or their central connections. The evidence is conflicting from sense to sense. According to Nagel[1] there is no good evidence that colors can be excited except from the retina. Cutting the optic nerve or turning the eyes sharply to one side or the other gives rise to sensations of light, but he thinks both probably due to the accompanying pull upon the retina. Sensations of taste are with difficulty or not at all excited by inadequate stimuli upon the tongue, while mechanical stimuli upon the chorda tympani where it passes through the middle ear arouse them certainly and at comparatively slight intensities. In the skin it is apparently the end organ that gives the peculiar quality. Pressure upon the ulnar nerve gives sensations but not of the distinct qualities that may be aroused from the skin. One cannot

[1] Nagel, Handbuch der Physiologie, Vol. III, pp. 1–15.

decide definitely between sense organ and the more central regions. Of the central nervous organs, it seems that the nerves themselves are relatively indifferent. They conduct in either direction, and sensory nerves may be made to carry motor impulses by giving them connections with motor structures. Whether the cortical centres have a specific function is still an open question. It has been assumed by many authorities that the qualities of sensation depend upon the parts of the cortex excited. No actual evidence for it has been collected and it seems improbable that it could be obtained. In general, it may be said that the doctrine of specific energies of sensory ends lacks much of complete demonstration, but that what data we have tend to support rather than to refute it. On disputed points evidence is wanting rather than opposed.

## Studies in Sensation Intensities. — Weber's Law

Sensation intensities offer an entirely different problem from qualities. Qualities, as we have seen, are ordinarily named, may be referred in some cases to sense organs, offer points of discrimination that may be recalled in memory, — in general they stand out for themselves. Intensities, on the contrary, have none of these characteristics. We think of a sound as very faint, moderately or very loud, but that is all. Intensities have no real designations, and cannot be remembered at all accurately. It is perhaps not one-tenth as bright in this room to-day as it was when last the sun shone, but you do not appreciate the difference accurately. You think of this as a moderately dark day, but have little idea how much darker than yesterday. The same holds of weights. Most persons have great difficulty in deciding whether a package of an unknown substance weighs one pound or two, and would be altogether at a loss to

decide whether more energy was exerted on the ear by a telephone held close to it or by a steam whistle at a distance.

**Measurements of Sensation.** — It has long been a problem among psychologists as to how intensities may be treated. The modern discussion of the matter may be said to date back to Fechner, who thought it would be possible to obtain a unit for the measurement of sensation intensities analogous to those employed in physical measurements. His assumption was that the barely distinguishable sensation difference, the difference limen as he called it, might be made a unit and any given sensation might be measured in terms of the number of such units it contained. This assumed that the only judgments that may be passed on intensities are that the sensation is or is not present, or that it is greater or less than another. The amount of sensation intensity that may be just noticed, the limen, was chosen by Fechner as the zero point in his scale. If one should start with the faintest sensation that comes to consciousness, and determine the addition that can just be noticed, the liminal sensation might be called sensation number one; the just noticeably different sensation, sensation number two; and if one should continue the process, it would be possible to determine the entire number of differences that could be noted in the series of sensations, and thus the entire number of sensation intensities in any sense department. It would also be possible to measure any sensation by the number of these unit intensities that were contained in it. Unfortunately, however, the facts are by no means so simple as this theory would assume. The least intensity that can be noticed is not fixed even for the same individual, and the number of units that can be noticed is also variable. In consequence,

this scheme, attractive as it is in theory, has never been and apparently cannot be applied in practice.

**Weber's Law.** — Out of the very large number of experiments devoted to these measurements, a law has developed that is of great interest. Very briefly, it has been found that the size of the just noticeable increment is not the same for all intensities, but increases with the absolute intensity of the stimulus, and bears a constant ratio to that intensity. Thus Weber found that if a weight of 32 ounces were lifted, it could be noted that 30 ounces was just less, while if 32 drachms were lifted, 30 drachms could just be noticed to be different. A difference of a fifteenth of the total weight could be noted whether the units were ounces or drachms. These relatively crude experiments have been repeated and improved upon by a number of later workers, Fechner in particular, and show the same general law. The fraction of the total intensity that may be just noticed varies from one sense to another, but holds with fair accuracy for the same sense. The values range from approximately $\frac{1}{100}$ for sight to one-third or one-fourth for smell. In giving these values, it should not be assumed that the just noticeable difference is absolutely constant even under constant objective conditions or under conditions that are as nearly constant as can be obtained. Differences in the order in which stimuli to be compared are given, in the degrees of attention at different times, and in the way in which the suggestions that may be given unintentionally may work, all have an influence upon the determination of the difference limen. In consequence, it is not often that two consecutive experiments will give the same result. All values given are averages obtained with the same individual, and where several values are given it is assumed that the two are extremes for the subjects used. Occasionally the

values obtained from different observers will be averaged, but this is not at present regarded as advisable. The results are not to be regarded, as in physics, as constant values that are obscured by the varying conditions of observations, but as fundamental differences due to the differences between individuals.

**Departures from Weber's Law.** — It is also true that the fraction varies for the different absolute intensities. It is always greater for the extreme intensities, and even within what may be called the mean values, there is often a gradual change. The first fact can be seen in many of the simple phenomena of daily life. The increase in the least noticeable difference at maximum intensities is illustrated in the difficulty in reading when the sun is shining on the page, as the difficulty in reading in faint light illustrates the increase of the relative difference at the lower range of intensities. The relative amount of light reflected and absorbed is the same at all intensities, but the relative difference that may be discriminated is much greater at the extremes of absolute intensities. Were relative differences discernible with equal ease at all intensities, one could read as readily by moonlight as by electric light, and in the glare of the sun as well as in the shade.

The values that have been obtained in the more important senses range for vision from $\frac{1}{85}$ to $\frac{1}{195}$ for different observers and different intensities. For hearing, Wien, using telephone tones, obtained a fraction of $\frac{1}{5}$ to $\frac{1}{8}$; for pressures, values have been obtained from $\frac{1}{10}$ to $\frac{1}{30}$, depending upon the part of the body stimulated. Lifted weights give a much smaller value than passive pressure, from $\frac{1}{20}$ to $\frac{1}{100}$, according to Biedermann and Lowitt, according to Weber $\frac{1}{40}$. Taste, smell, and temperature all offer difficulties in the technique, and the results are correspondingly unsatisfactory. The

values of the fraction for these senses are generally given as ranging from $\frac{1}{3}$ to $\frac{1}{4}$.

**The Limen for Sensation.** — The results of the investigations of the least intensities that can be perceived, the absolute sensation limen, have also been determined for certain senses with a satisfactory degree of accuracy. For sight and sound the values can be given in terms of absolute units. Langley found that the eye was sensitive to light waves that exerted an energy of .00000003 erg. Wien found that the ear would respond to still smaller values: from .000004 erg for tones of 50 V D per second to .0000000000000005 erg for tones of 3200 V D per second. For pressure, the most reliable results are those given by von Frey.[1] He found the energy required to excite a hair to be about $\frac{1}{50}$ of an erg, and to excite a pressure spot on the skin about $\frac{1}{3}$ of an erg. Values obtained for other senses have relatively little meaning, as they cannot be stated in terms of energy.

**Theories of Weber's Law.** — It can be asserted, then, that within limits Weber's law holds. Differences in two stimuli are noticed more easily when the absolute stimuli are low than when they are high, and the addition that can just be appreciated is a constant fraction of the stimulus already present. The explanations of this law fall into three groups. Wundt holds that the law has a purely mental basis, that it is but one expression of the general law of relativity; all things are estimated in terms of other things that may be in consciousness at the moment. This is merely a restatement of the law rather than an explanation. Fechner regarded the law as an expression of the general relation between body and mind. These were two phases of a single substance for him, like the inside and outside of a circle, and in some way not made clear, stimuli that

[1] Von Frey, Zeitschrift f. Biologie, vol. lxx, p. 333.

increase in a geometrical ratio produce an increase in mind in an arithmetical ratio. A third theory, developed in large degree by G. E. Müller, explains the law as due to the loss in intensity that a nerve impulse undergoes in passing through the nervous system itself. That such a loss does take place is suggested by the experiments of Waller with the optic nerve and retina of a frog. The current of action of the nerve excited by different intensities of light upon the retina was measured and it was found that the current of action was related to the intensities of stimulus in the arithmetical-geometrical ratio. Müller asserts that the more intense the stimulus, the more opposition is offered to its passage through the nervous system, and in consequence the more is lost, — a smaller proportion reaches the brain. If the amount lost — and so the amount retained — is proportional to the absolute intensity of the stimulus, the demands of Weber's law are satisfied. Ebbinghaus has suggested that this increased loss can be explained on the assumption that there are in the nerve chemical substances which decompose with different degrees of difficulty. The less intense stimuli use up the more readily decomposable elements, and hence produce a relatively great effect on consciousness, and the stimulus must exhaust an increasingly greater amount of energy in affecting the components next higher in the degree of difficulty of decomposition. Whatever the detailed explanations, the facts available indicate that the law is due to the increasing resistance offered in the nervous system to the transmission of the more intense nerve impulses, that the explanation is physiological rather than psychophysical or purely psychological.[1]

[1] Titchener, Manual of Psychology, Instructor's Manual. Quantitative.

## CHAPTER VI

## THE ORIGINAL NATURE OF MAN, AND THE MEANS OF MODIFYING BEHAVIOR

WE have now summarized the more important facts which are preliminary to any study either of the behavior of man or of his consciousness. The nervous system makes possible all activity; and the sense organs through their stimulations supply the incentives for all movement and also provide the materials that are manipulated in the acquisition of knowledge of any type. The nervous system has within it at birth the connections that make possible the instincts and reflexes; potentially it has the capacity for forming the connections upon which depend all acquisition of habits, and the form of learning which we popularly call memory.

**Nature and Nurture.** — When we turn from the discussion of the physiological structures, which must be understood prior to any study of psychology, to the actual investigation and explanation of man's activities and life, there are two opposing tendencies which must be taken into consideration in the explanation of every phase of conduct and of thought. These are known roughly as *instinct* and *habit*, or even more generally as nature and nurture. Briefly these terms mean that the man is determined in his responses and in his thinking by characteristics inherited from his immediate ancestors and from the race as a whole, and by certain other characteristics developed by the environment in which he lives. The one is present at birth

or is the immediate outcome of the growth of his nervous system; the other is a direct product of living and learning, of his adaptation to the world about him. These two opposing groups of forces are frequently difficult to distinguish, and they almost always interact in determining both the general capacity of the individual and the nature of his specific responses to any given situation. Still they must be regarded as distinct in our discussion.

The native endowment of the individual includes both the capacities distinguishable at birth and those which are to develop later. If one look at a new-born infant and study its responses, one sees in it relatively little of the powers that it is to develop. An occasional cry, a few reaching movements, and the reactions of nursing, give about the only evidence of intelligence. There is no way of determining at this stage what the future capacity is to be. An observer could not tell a future Darwin from a possible criminal or imbecile by any of the tests known to science, if he did not have a knowledge of the heredity of the child. Even an acquaintance with the heredity gives only the possibility, not complete assurance, of the career that is to be. Nevertheless we must believe that a large part of the accomplishment of the child is already determined. Training and the effect of environment will serve to bring out what is already there, but in the absence of certain as yet unknown characteristics of the nervous system, no amount of training or stimulation would suffice to produce great ability.

Two fundamental forms of native endowment may be distinguished. One determines the specific responses of all individuals of a species to given situations; these are the reflexes and instincts. The other determines the more general capacity for learning and response, the intelligence,

temperament, and disposition of the individual. The reflexes and instincts we regard as the forces that make all individuals respond in approximately the same way; the other forms of equipment give rise to the differences between individuals. Both are due to heredity. The first group designates the inherited similarities in response; the second, the inherited differences. Another distinction is that the instincts and reflexes show themselves in actual responses, while the other terms indicate only capacities for responses or for learning, or the tendencies to emotion.

**Intelligence, Temperament, Will.** — We distinguish three ways in which individuals may differ in capacity: in intelligence, in temperament — or the liability to certain emotions, and in the volitional characteristics of action — the qualities of the will. The definition of these terms has gone little farther in psychology than in popular usage. By intelligence we mean the ability to think to good effect, to appreciate situations, and easily find the solution for the difficulties they present, to appreciate ends and to be able to work consistently towards those ends. In practice, intelligence goes very closely hand in hand with the ability to maintain one's self in a given environment, physical and social. The temperaments are not clearly differentiated, although all admit that both for scientific classification and for the treatment of mental diseases, it is desirable to push our analysis farther and to secure tests that shall measure temperamental differences. The volitional characteristics are also important, but we know only that differences in the ability or willingness to work persistently to a desired end influence markedly the success of individuals of the same intelligence.

## INTELLIGENCE TESTS

**Binet Tests.** — Tests of intelligence have been developed in great number and several of them have been standardized to the point where the wider differences may be measured with considerable accuracy. All are alike in requiring the individual to be tested to carry through a number of relatively simple mental and physical operations in which he may be rated for quickness and accuracy. The two tests which have had the widest use and are in many ways best adapted to the purpose are the Binet tests and the tests developed for the examination of the intelligence of the United States soldiers in the World War and consequently known as the Army Tests. The Binet tests were developed on the assumption, which the outcome verified in general, that one might measure the intelligence of any one below the average intelligence, by comparing his accomplishment in a series of tests with the accomplishment of a child of some given age. It was assumed that the child begins with approximately zero intelligence, and then passes through all degrees until, if an average child, he reaches average adult intelligence. Binet devised a group of tests for each age, which the average child of that age could just pass. These were tested on a large number of children and in actual practice arranged in groups on the basis of the results obtained. The tests ranged in difficulty from naming the parts of the face and simple objects, to defining abstract words and stating the difference between a king and a president, on to complicated arithmetical puzzles. Much depends throughout upon memory for immediately preceding events, upon the amount learned from what is assumed to be the environment of the normal child, and upon ability to appreciate situations and apply simple remedies in

case of difficulty. One test alone would have little significance, but a number taken together give a fairly accurate idea of the capacity of the individual.

**The Mental Age and Intelligence Quotient.** — Binet's most important contribution to the methods of testing was in using the capacity of children of different ages as a standard of comparison. After one has discovered which of the group of tests the individual can pass, one has a measure of his intelligence in years, which is now generally called his mental age. If of average ability, his mental age and his chronological age are the same; if he has developed more slowly than the average child he will be retarded by one or more years. The mental age gives an immediate indication of the intelligence of an adult. The mental age scale is applicable readily and satisfactorily to children and to defective adults. Since the average child reaches his maximum development at thirteen, it is obvious that the measure cannot be used for adults of more than average ability. Recently in revising the scale, Terman suggested that one could state the intelligence of an individual irrespective of his actual age, if one used the ratio of mental age to chronological age as the index of intelligence. If one divide the mental age by the chronological age, one obtains what he calls the *intelligence quotient*, usually abbreviated as the I. Q. The I. Q. of the average individual is 100. The justification for using the ratio of mental to chronological age is that tests show that this ratio remains fairly constant throughout life. If a child is one year behind at four, he will usually be two years behind at eight and three years behind at twelve. His I. Q. would be constant at 75. If a child were one year ahead at five, he would similarly be two years ahead at ten and would have an intelligence quotient of 120. One limitation of the method

is that only a young child can make a very high rank. The highest age for which tests are given by Terman is twenty. In consequence, a child of sixteen would be limited to an I. Q. of 125, while a ten-year-old might make 200. The tests beyond fourteen have little relation to the accomplishments of actual children, as few children reach that level.

**The Distribution of Intelligence.** — So far as results go, intelligence seems to be distributed in accordance with

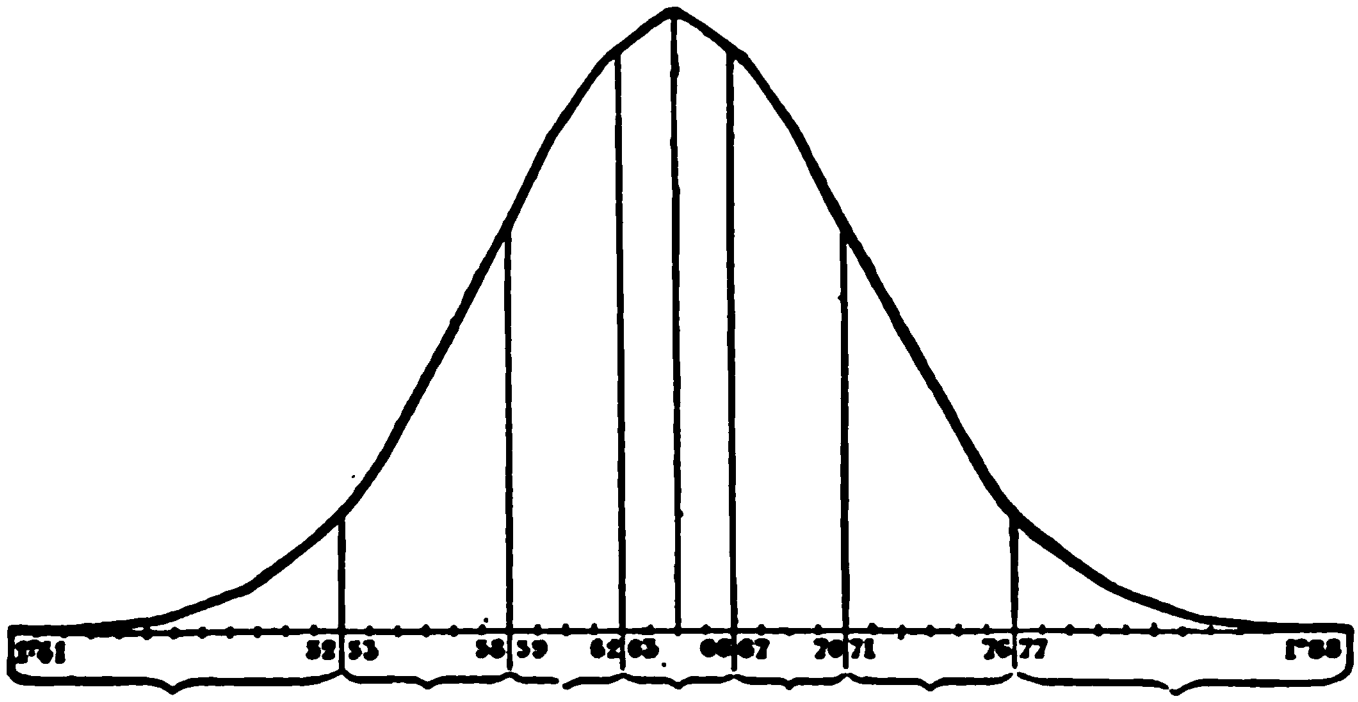

Fig. 70. — The distribution of stature among French soldiers. The distances on the horizontal axis indicate the height in centimetres, on the vertical axis, the number of men of heights between the figures printed below the line. (From Bertillon: Instructions signaletiques.)

what the mathematician calls the normal frequency curve. It is the curve that results if one plots a large number of measurements of any kind on unselected individuals. Figure 70 shows the curve that results from plotting the heights of a thousand French soldiers, indicating the height in centimeters above 100 on the base line and the number of individuals who are of the given stature on the vertical distance. The average in this case was 164½ cm. There are just as many who are taller as shorter, and the greater the distance from the average the fewer are the individuals represented. There are 236 between 163 and 166, but only

10 each who are less than 141 cm. or more than 180 cm. tall. Terman found that intelligence is distributed in the same way. About 60 per cent fall within ten points on either side of the average, and have an intelligence quotient between 90 and 110. These are the average individuals. There are about 14 per cent between 80 and 90, and between 110 and 120; about 5 per cent each in the next range of ten points to 70 below and 130 above; and 1 per cent below a quotient of 70 and with 130 and above. Those below 70 are ordinarily counted as feeble-minded; that is they are sufficiently deficient to be likely to become a charge on the community, while those above 130 are exceptional, and are ranked by Terman as geniuses or near geniuses.

**The Army Tests.** — In the Army Tests the method of measuring capacity is to compare the accomplishment of the individual with the performance of a large number of other individuals and give him a rating relative to the group. It consists of a series of questions to test arithmetical skill, general information, ability to understand and follow directions and to comprehend different relations. It could be given in less than an hour to two hundred or more men at once, and as it was given to a million and three quarter-men, the results sufficed to give an excellent idea of the distribution of intelligence in the general population. Like the Terman test, it shows that the distribution of intelligence follows the normal frequency curve. The total possible score was 212. On both tests the intelligence was found to be symmetrically distributed. About 4 per cent made a better score than 140 and about 7 per cent made a lower score than 14. The first were designated as an A group, the lower as an E; similar intermediate grades were made. The men of the A group were found to be of intelligence suited for high command, provided they had the emotional

and E group men were from the
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tions of certain individuals for the higher types of training and even for life in society. The schools have found the tests of value in sorting out those who are incapable of doing good work or of keeping up with the grade. The worst must be given a special kind of training; and the better types, when put by themselves, can be taught by different methods and permitted to learn at a faster rate. Tests of prisoners in civilian life, particularly the juvenile prisoners, have shown that many of them are below normal mentally, as are also many of the paupers and others who have difficulty in maintaining themselves. Recognition of the differences in intelligence is necessary to an understanding of many social problems.

## Character Tests

**Investigations of Character.** — Differences in emotional and volitional characteristics undoubtedly exist, but accurate measurements have not been made of them. So far no scheme of measurement has been devised, much as that is needed, particularly by the specialist in nervous diseases, since emotional disturbances are strikingly frequent in the causation of such troubles. An investigation by Webb sought to determine the differences by having the degree in which individuals possess certain traits rated by judges who knew them well. He chose certain characters that are fairly easy to note, such as readiness to anger, eagerness for admiration, bodily activity in the pursuit of pleasure, persistence of motives, continuance towards a goal in spite of obstacles, trustworthiness, conscientiousness, etc. He found that certain of these traits correlated closely among themselves. They could be divided into two classes: a desirable group, including persistence of motives that lead towards a remote goal, quick recovery from anger, conscientiousness,

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who fail because of lack of persistence or of so
bility. Fortunately these are the exception
the rule.

## Individual Differences

**The Coefficient of Correlation.** — In dis-

of correlation. For example, in order to determine the relation between intelligence and stature, one may measure the degree of connection by arranging a large number of individuals in their order with reference to each of these characters and determining the relative ranking in each. Should there be a complete identity between the two traits, the individual who ranked first in one would be first in the other; the individual who was second in one would be second in the other, etc. If this relation held, we would have a coefficient of correlation of 1.0. On the other hand, were height in some way inimical to intelligence, we might find that the shortest individual was most intelligent, the next shortest ranked second in intelligence, and so on. In the case of such a relation, we would have a coefficient of −1.0. Such absolute agreement is never found. What we do find is that many of the men who stand high in one, will stand high in the other also; while in the case of negative correlations, many or most of the men who are above the average in one will be below average in the other. These are represented by numbers between zero and 1.0 or between zero and minus 1.0; the nearer 1.0, plus or minus, the greater the degree of similarity or dissimilarity. The methods of obtaining the exact values may be found in treatises on statistical method, Yule's "Theory of Statistics," for example. A coefficient of correlation seldom is above .90. One below 0.35 indicates relatively little similarity, unless obtained from a very large number of individuals. Such a correlation as that between height and standing in mental tests would be possibly 0.5–0.10. It seems to be positive but so slight as to indicate nothing. The correlations between common sense and readiness to anger, in Webb's work, was −.53; while that between common sense and originality was 0.84.

**The Causes of Individual Differences.** — When we raise the question of the origin of the differences in intelligence or in temperament, we find that there are two possible answers. On the one hand we might assume that all was due to heredity or that all was due to training. The other answer would involve both influences, attributing part to heredity and part to training; if this were the case, the problem would be complicated by determining what the share of each might be. The evidence is largely supplied by statistical studies.

Most work has been done upon the origin of intelligence. The lack of intelligence or feeble-mindedness seems, from Goddard's results, to be a recessive trait, which follows the laws of Mendelian inheritance quite as accurately as do the transmission of colors in plants, or shagginess in the guinea pig. Goddard traced this trait in several hundred families in New Jersey and found that one could predict the appearance of feeble-mindedness in the children with the same accuracy that one could predict the shape of the leaf from crosses of plants.

Studies of the intelligence of school children by the Binet tests indicate that the intelligence of children who come from the better homes is about a year higher on the average than is that of those who come from poorer homes. One might attribute this to training as well as to inheritance. If we assume that the individual with the better home and social standing is more intelligent and has reached his position because of that intelligence, the parent who is responsible for the heredity of the child is also responsible for his training. That it is heredity rather than training is shown from the fact that occasionally one will find a child of high intelligence in a poor home, while placing the child of unintelligent parents under the best of training will not increase his intelligence.

Studies of heredity as shown in the biographies of eminent men indicate not merely that intelligence in general is inherited, but also that specific types of intelligence are transmitted. Galton traced the ancestry and descendants of eminent Britons of all callings, and found that children of distinguished men had a very much greater chance of being eminent themselves than did the child of average parents. Sons of justices were likely themselves to be distinguished jurists, sons of distinguished scientists were likely to be scientists of high rank, and children of artists were frequently successful in art. Wood, in a similar study of royal personages, found marked tendencies to the inheritance of abilities and of defects. One might argue that the specific direction of the interests of the child of the commoner might be dependent upon living with the parents and the opportunities that were implied by that. Undoubtedly there is some element of environment included in the influences that determined the men whom Galton studied. In royalty this factor would be reduced, since, so Wood argues, the environment for all royal children is approximately the same. Nevertheless the traits of the parents can be traced very clearly in the offspring through a number of generations.

Another statistical study of inheritance by Pearson confirms the result. Pearson asked teachers in all parts of England to estimate the standing of brothers and sisters with reference to easily described traits, and then calculated the coefficient of correlation for the traits in pairs of brothers and sisters. He included ability, vivacity, conscientiousness, temper, and assertiveness, among his traits. He found a coefficient of correlation between children of the same parent of about 0.50. This is approximately the same as the coefficient for different physical measurements. In

the rough, it means that mental characters are as likely to be inherited as are physical characters. It will be noticed that several of his traits belong in the emotional and volitional group. This so far tends to confirm common observation that these are inherited as well as, and in approximately the same degree as, the intellectual differences. Taken together the evidence is conclusive that differences in mental capacities and in volitional and emotional disposition are specific heredities from the immediate parents.

## Habit Formation

**Instinct and Habit.** — On the other hand there are groups of characteristics which are also inherited that contribute to make the individuals similar. These are the instincts. While present in different degrees in different individuals, they are represented in all individuals and may be considered the factors that serve to produce uniformity in the race as a whole. Very briefly we may assert that similarity in response to the same stimulation, the similarities in aims and in mental activities when not due to similar education or to living in the same environment, are to be ascribed to instinct. These instinctive responses range from those which are fundamental to the life of the organism and serve to keep the individual alive until he learns to take care of himself, to the appreciation of the essential or desirable in external stimulation and in his own aims. The definite study of the instincts in their origin and effects we may leave to the next chapter. Suffice it here to indicate that there are these movements and forces in the control of behavior and mental life in general which are due to the connections innate in the nervous system. In discussing the reflexes in the chapter on the nervous system, it was seen that the simple actions were determined by the ready-made connections

between different neurones at the synapses. The instincts have the same general explanation. They, too, are the result of the openness of synapses at birth. The difference between the two is, first, that the instinct is usually a larger group of movements tied together in a single complex whole; secondly, that the movements are characterized by their coöperation to the attainment of a definite end; and in the third place, the movements involved in the instinct may be more variable, the end is apparently determined, but the movements by which the end is attained may be varied with the circumstances or through the learning of the individual.

**The Formation of Habits.** — The other factor in the life of the individual which requires preliminary mention here is the formation of habits. On the motor or behavior side this is the complement of instinctive activity. Certain of the movements of the organism are as fixed as the movements of a machine, at least of a machine that is loose in the gearings and as wobbly and uncertain in its movements as the worst conceivable machine that will run at all. By far the greater number, however, are adjusted to the separate stimuli by a series of tentative movements, and become fixed, if at all, only after a number of trials. The higher the animal, on the whole, the smaller the proportion of responses that are determined by instinct and the larger the number that must be acquired by the individual himself.

**Learning is by Trial and Error.** — This process of learning is always by a series of trials with numerous failures and long-delayed successes which only gradually approximate the end desired. This is known as the process of trial and error. Fundamentally it is probable that each separate movement is prepared by an open connection or connections

in the nervous system. However, so many paths are open that many different responses are made in succession to the same stimulus, and the apparent result is that chance determines what the first reaction shall be and the order in which it shall be followed by other responses.

Studies on animals under experimental conditions indicate very clearly the nature of the process. If a hungry cat be put into a box with a door supplied with a catch which can be opened from the inside, and a bit of fish placed near, the following series of learning processes will be noted in typical cases. Biting the catch, and biting without definite object near the door and at all other places that look promising, will be succeeded by scratching, and even by cries. Sooner or later some one of these movements is pretty sure to open the door and permit the cat to walk out. Learning in animals is seldom complete with one performance. If the cat be put back, it will have to go through a similar series of uncertain movements before it gets out again. The time required for escape will be lessened at each trial, until finally it will make the correct response as soon as it is put into the cage. Learning by the child also follows the method of trial and error. When the baby learns to creep, the first movement is by chance. Some children make their first movements by hitching forward as they sit up. If this is repeated sufficiently often it may become established as a habit, and unless the regular crawling movement or some other more effective means of locomotion happens to be hit upon, the child may use that alone until he learns to walk. Some children hit first upon the series of movements that will push them backwards — occasionally one will develop the habit of rolling over. Whichever develops first will be used until a new and more satisfactory method is hit upon. In many cases the first method,

even if awkward, will be continued until the child begins to learn to walk.

This trial and error method is followed in the acquirement of every kind of movement; it persists to the acquisition of the most important and complicated movements of adult life. From these simplest first movements through to learning a complicated industrial process or a new game of skill, the process of learning is one of chance movements and elimination of the unsuccessful attempts.

**Learning as a Nervous Process.** — If we analyze the mechanism of the process a little more closely, we can see that the requirements are: first that the individual shall have a large number of possible movements at command and shall know when the desired object is attained, or possibly shall have the capacity for discriminating between the beneficial and non-beneficial, either in advance of the movement or after the result has been gained. The first capacity is due to the spread of the impulse from the sensory neurones first aroused to as many motor neurones as possible. This spread through the untrodden ways of the cerebral cortex is very much like the formation of association, save that there is not even the simultaneous activity of some other area to guide the course. Every impulse of even moderate strength seems to pass over into motor discharge. When a sensory neurone or group of sensory neurones is aroused, the impulse tends to spread to motor paths, even if there has been no previous excitation of that group of neurones or sense organs. It has sometimes been suggested that each response must have been developed in the brain previous to birth, — must be in part of instinctive origin, — but the number of apparently new combinations makes it seem that many parts of the cortex have open pathways between them over which the impulse may take

its course. The many alternative paths make learning possible.

**Selection of Habits Determined by Instincts.** — When a stimulus affects the sense organ, one group or series of synapses after another will be opened, and a corresponding movement made, until a more satisfactory condition is attained; that is, until the stimulus, if unpleasant, has been removed or a more complete stimulation by a pleasant stimulus has been obtained. These successive paths are opened in the order of permeability of the synapses. The determination of what response shall be accepted and repeated until it becomes a habit is the essential phase of the whole process. The selection is fundamentally innate or instinctive in character. What shall seem suitable to the individual depends upon his inherited disposition, influenced to some extent possibly by his training. When the result of a movement is pleasing, either in general or in the particular setting in which it occurs, it will be repeated. With repetition it will become a habit. In this way the control of habit formation is exercised through instinct. Since many movements that are ordinarily called instincts are not perfect at the first performance and need a number of trials before they reach perfection, it is evident that most of what we call instincts are definitely similar to these habitual processes. Both belong to the same class, but lie at opposite extremes. All movement depends upon both instinct and learning. One element may greatly predominate over the other. After the response that gains satisfactory results chances to be made, it will be repeated until the synapses that lead to it will be more completely open than any of the others. When the habit of making this response is established the particular movement will always respond to the given stimulus.

**Pleasure a Guide to Learning.** — The *modus operandi* of the instinct in the formation of habit is not altogether agreed upon. In part it seems that the mere pleasantness of the result itself serves to facilitate learning and so leads to habit formation. At times it seems that the mere pleasantness makes a response whose result is pleasing more likely to be repeated, and so the learning is due to the frequency of repetition alone. In other instances it seems that the pleasure itself serves to make the pleasant response more permanent, to have a greater effect upon the synapses than the unpleasant. Certain it is that the pleasant response becomes established, while the unpleasant is eliminated. One element in the process may be the frequency of repetition when a stimulus recurs that has evoked a response with a pleasant result. The old pleasure-giving movement will be repeated, while the unpleasant response evoked by a stimulus will be checked when it reappears later. This leads to a more frequent repetition of the pleasant response than of the unpleasant. Often this takes the form of one movement when the stimulus itself is pleasant, and of another when it is unpleasant. Usually withdrawal comes with displeasure, approach with pleasure. A case of opposed response is illustrated by the learning to peck and swallow of the moor chick reported by Lloyd Morgan. The chick at first pecks at all small objects. When a disagreeable one reaches the mouth it is ejected, while the pleasant one will be swallowed. After a time the unpleasant will not be picked up. The unpleasantness of the result serves to prevent the pecking response, although the immediate effect is to reject the food. The terms 'pleasant' and 'unpleasant' are probably the mental accompaniments of the benefit and injury which are instinctively appreciated.

This trial and error process, then, is made possible by the

numerous potential connections in the nervous system between sensory and motor neurones. It is checked and controlled by the instinctive awareness of benefit and injury which is revealed in the pleasantness and unpleasantness of the results of stimulation and of action. All action is a resultant of these two processes: chance trial and control by instinct.

The division of actions into two distinct parts, a more or less uncontrolled evocation of the process through chance connections on the one hand, and a control or selection by consciousness of what is suggested, on the other, is typical, we shall find, of mental processes as well as of physical. Whether we be thinking, or recalling, or imagining, we usually have a rather uncontrolled and irregular series of trials first, and then gradually hit upon some movement which is approved and accepted. We must always distinguish between the arousal and the acceptance or rejection of any process, be it motor or sensory.

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# CHAPTER VII

## INSTINCT

We come now to consider the second form of innate tendencies or capacities which determine the responses and finally the character of the individual. These are the instincts. As opposed to intelligence and the general emotional and voluntary characteristics, which are merely capacities for larger groups of responses, instincts are either specific responses or tendencies that control the character of the specific responses. They may also be opposed to the above mentioned group, they are the endowment of the race as a whole rather than of any family or individual. They give unity to the race, since all men share in the instincts, while intelligence and temperament serve rather to emphasize the differences of individuals.

The term 'instinct' is used to designate a large number of different processes, activities and tendencies to activities. So general has been the use of the word, in fact, that some writers desire to give it up as too vague. However, so many important facts may be grouped under the term, and the series of activities it describes is so important, that it seems much better to retain the word and to state clearly just what it is and what it is not to mean.

### The Nature of Instinct

**Definitions of Instinct.** — Two distinct meanings of the word *instinct* are current. The first defines instinct as a movement or series of movements evoked by a particular

stimulus. The second defines it in a way to make it little different from the learning by trial and error mentioned in the last chapter. It is constituted by a series of tentative movements guided to an end by the pleasures that attach to possession, or the discomfort that results from lack of the object or condition that constitutes the end. Here the movements are not prescribed, in fact, vary greatly from situation to situation. What is instinctive is the pleasure or displeasure which impels to movement and assures the attainment of the end.

The first is used to designate a more complicated reflex. Thus, the pecking at a grain of corn by a newly hatched chick, and the complicated series of movements by which it breaks its way out of the shell, are instincts of the first type. An excellent illustration of the simple instinct dependent upon the stimulus and not modified to meet changing conditions is that of the solitary wasp noticed by Fabre, and quoted by Hobhouse as follows: "A solitary wasp, *Sphex flavipennis*, which provisions its nest with small grasshoppers, when it returns to the cell leaves the victim outside, and goes down for a moment to see that all is right. During her absence M. Fabre moved the grasshopper a little. Out came the Sphex, soon found her victim, dragged it to the mouth of the cell, and left it as before. Again and again M. Fabre moved the grasshopper, but every time the Sphex did the same thing, until M. Fabre was tired out." Instincts in this sense are more complicated than the reflex, involve a greater number of muscles, and a larger number of movements in a series. The line between reflexes and instincts thus defined is difficult to draw. Just how complicated a reflex must be to become an instinct is not easy to say. It has sometimes been asserted that instincts are more purposive, reflexes more mechanical,

but even this distinction is not very clear, since most reflexes as well as instincts have a purpose even if reflexes are explained by mechanism. Again, there is always an implication in instinct that we are dealing with something that is or might be conscious, that is like voluntary action. But this is mostly an analogy, and, since instincts are very frequently not conscious, or we can only infer that they are conscious, even this criterion is not susceptible of accurate application. Instinct in this sense is a movement made in response to a stimulus or a group of stimuli as a result of inherited connections in the nervous system, a movement more complicated than a reflex, either in the number of stimuli that call it out, or in the number of muscles that are coördinated in its execution. In many minds, but subordinate to this distinction, is the further implication that the instinct is purposive, and more like voluntary or conscious movement than the reflex.

**Variation in Instinct.** — As opposed to this rigidly determined series of movements, most instincts show considerable variation and reach the final end by various ways. The hunting instinct of a cat, as exhibited in catching and killing mice or birds, adapts itself to the circumstances. Only the crouching as the prey is approached and perhaps the final spring are even approximately uniform. The cat usually plays with the mouse after it is caught, but even this is not a mere mechanical repetition of the same movement or series of movements. The resemblance between acts at different times is at best general. The reaction is to a number of separate stimuli each of which calls out a separate act, and the whole series is bound together by the general end. Probably, even here, each separate act is the result of a definite stimulus, but the connecting link that makes the whole a unit is found in the preparedness induced in

the animal by one act which makes it more readily affected by a stimulus of the same group rather than by any other. The whole may be pictured as held together by an inherited tendency for the acts of the entire series to respond in succession to definite sorts of stimuli. But there is much variety in the way in which the end is reached, due apparently to the fact that instead of preparing the way for one set of responses alone, a number of responses, each of which may lead to the desired end, are rendered more easy. Whenever a stimulus presents itself that excites any of the group of movements, the way is opened for carrying out all the others.

**Instincts as Ends.** — Instinctive activities of the second class are still less definite in character. In the extreme instances of this class little is determined by inheritance other than that the desired end shall be attained. The attainment may be by any method that previous experience or the acquired habits shall dictate. The desire, not the movement, is instinctive. In this second class belong very many if not most of the complicated instincts manifested by the human adult. Acquisitiveness, combativeness, sympathy, and the great mass of instincts that may be regarded as protecting the human individual, the family, and the social group, are constituted of movements that have no regularity, but nevertheless drive the individual to a fairly definitely prescribed end. Thus, we speak of mating as an instinct, but the preliminary instinctive responses of coyness, and the whole series of courting activities, whether in the higher animals or in man, are indefinite. At the more reflex end of this class are movements that seem to be directed toward a definite end, but the separate responses are not each dependent upon the preceding act and the stimulus, but are complex mixtures of learned

movements with a few reflexes. In simplest form the second class is different from the more general forms of the first only in the fact that movement and the stimulus are not so closely joined. One of several responses may be made to the stimulus. Again, one movement of the series does not follow so mechanically upon the preceding. Finally, the end is more in evidence. This end may be foreseen, although the reason for the dominance of that end or purpose is usually not appreciated. At the other extreme of this class, what is instinctive is the pleasure that accompanies the attainment of the purpose rather than the concatenation of movements that shall lead to that end. The acts made when one sees a beggar may vary from giving money to turning away as quickly as possible, but the feeling of pain that impels to some action is due to inherited causes.

The term *instinct*, then, is used to indicate all acts whose conditions are inherited. It matters not whether those acts may be referred to specific inherited connections in the nervous system or whether the act is the result of striving for an end which some innate predisposition compels the individual to strive for, and whose attainment gives pleasure. While this definition is broader than that explicitly given by many psychologists, all extend the term in practice to cover acts that belong only to our broadest class. At present most men incline to make instincts primarily reflexes of greater complexity, and to reduce as many as possible to the simpler forms of response. This is the more satisfactory, as it reduces to a minimum the natural tendency to vagueness and the introduction of mystical forces. Even where instincts cannot be explained in this simplest way, there is no need to resort to the mystical, since the dispositions and preparatory irradiations may all

be assumed to be due to the inheritance of specific dispositions in the nervous system, even if we cannot at present say exactly in what they consist.

## Specific Instincts

**Classification of Instincts.** — The specific instincts are differently classified, and no complete agreement exists as to what shall be regarded as instinctive, even when the definitions have been settled. MacDougall limits instincts to flight, repulsion, curiosity, pugnacity, self-abasement, self-assertion, and the parental instinct (under which are placed care of the child, sympathy as an outgrowth of care for the offspring, and, by development, moral indignation). Minor instincts are reproduction, gregarious instincts, construction. Watson in his study of animals has eleven classes, — locomotion, obtaining food, shelter, rest, play, sleep, taken together as the basis for the daily and seasonal routine; sex, defence and attack, migration, mimicry, vocalization; and two less definite groups. It can be seen that almost all of MacDougall's list belong to our second class. Watson's are fairly evenly divided between the two. Some add more, others question some of these, but there is probably no chance of close agreement among all as to just how many groups there are, or even what specific acts shall be included in any group.

It will be best to make a general classification with reference to the end that the act subserves, rather than to the specific character of the particular instinct. One of the most convenient divides instincts into three classes:

1. Those which preserve the life and provide for the welfare of the individual;

2. Those which provide for the continuance of the race and for the family;

3. Those which make for the welfare of the tribe or of the social unit.

Some of the acts belong to more than one class, — in fact, no one of the second or third would be possible without the first, — but the division is convenient in general and may serve as a guide through the maze.

**Individual Instincts.** — Among the individual instincts we have those necessary for the care of the individual in the early stages of life. One of the best instances is found in the pecking its way out of its shell by the young bird. This instinct, according to Craig, is always carried out in very much the same way, although involving two important separate movements: pecking itself, and so turning in the shell that the shell may be broken in a continuous ring. Here, too, belong the first movements of taking food, which make their appearance almost at once, and change their character as the needs of the organism develop. Other individual instincts are involved in locomotion, walking, flying, or swimming, the care of the body in matters of cleanliness, the preening of the feathers by the bird, licking the body by cats, dogs, etc., the persistent hunt for parasites that seems to occupy a large part of the spare time of all monkeys and apes, stalking game, fighting, flight from larger animals, in sum an imposing list.

**Instincts of Human Infancy.** — In a recent careful study of several hundred infants in the maternity ward of The Johns Hopkins Hospital, Watson found that the number of instincts exhibited by infants up to 200 days was much smaller than is usually thought. He found only crying, nursing, grasping, movements of defence, eye-coördination, blinking, manipulation, and fears of falling and of loud sounds. The child from birth can support itself, will push away an object that injures it, and will feel about and inves-

tigate any object that it can reach. On the other hand, Watson saw no evidence of instinctive swimming movements, of right-handedness, nor of withdrawal from filth. It is not claimed that some of the more complex instincts may not appear at later periods, but at the later period they would be mixed with learning and would probably belong in the class of instincts which are determined by the desirableness of the end, rather than of simple predetermined movements. It appears certain that the purely instinctive movements are relatively few in man.

**Fears.** — The more highly developed and complicated activities of the adult are many of them guided merely by the instinctive pleasantness of the end sought or the instinctive disagreeableness of the object avoided. This is true in large degree of the responses in fear, although some of the movements are fairly constant and common to many men. They show themselves in practically all men, although to be sure in different forms and in different degrees. In most cases they are not to be explained from experience, and many are absurd in the light of experience. Why a grown woman should be so startled by a mouse, why a man should make such exaggerated responses when a harmless snake wraps itself around his ankle, are hard to understand in the light of experience alone. Similar are the trembling at looking over the edge of a precipice from behind a perfectly secure railing, the fear of the dark, of caves and strange places, of the dead, and hosts of others that the reader may supply from his own experience. In the development of a child, these fears come one after another and frequently disappear almost as suddenly as they appear. For a few weeks or months a child will be afraid of fur, then the fear disappears and fondness for it replaces the fear. A cat may suddenly become an object

of terror, and later, without other experience of cats, may arouse all signs of pleasure. Thus, the early life may be a constant succession of fears that come apparently with the stages of development of the nervous system. Interesting, too, it is to note the tendency of those fears to become exaggerated in diseased conditions of the central nervous system. Here we find fear of open places that leads the victim to slink around the sides of parks rather than walk across them (agoraphobia), and also, the opposite tendency, to fear all closed places, to avoid rooms and narrow streets, and to feel at home only in the open (claustrophobia). These are but two of many morbid fears.

Among the instincts that aid to make up the individual character by the amount they contribute to the sum total of his instincts are pugnacity, the tendency to accumulate, and curiosity. The degree of pugnacity is one of the most important individual characteristics. It varies from the extreme in a tendency to domineer over every one, through a moderate degree of self-assertion, to a minimum in the weakling who never asserts himself. The one man never admits that he is wrong, will never see that he is beaten, but fights on to the end. Tempered with proper discrimination of what is worth fighting for, this constitutes one of the elements in all strong characters; untempered, it makes the quarrelsome bully. The man in whom it is badly developed is ready to give up with the first disappointment, if he permits himself to get involved at all. Closely related, if not identical, are the qualities of courage and cowardice. The collecting instinct is not quite so clearly demonstrable as an instinct, but the piling up of hoards of all kinds beyond the probable or even the possible needs of an individual seems to demand an explanation other than habit or reason. The intense pleasure which comes with

the large accumulation is indicative of other than acquired characteristics.

Curiosity is a striking character in the attitude of the higher animals as well as of men. The dog, the cat in less degree, monkeys in the extreme, show a tendency to examine all strange objects. From their acts one might argue that they were intent on understanding them. Certainly in man there is a pervading restlessness until all unfamiliar objects and movements have been examined and explained, — an instinct that shows itself early and persists with increasing intensity until well into old age. In its simple forms in the child or in the uncultivated it impels an investigation of all possible sources of danger and provides for the security of the individual. In its higher forms it may well be regarded as the source of very much of man's desire for knowledge and of the growth of science developed from it. Much of this knowledge is probably useless from the practical man's standpoint, and in any case the investigations that lead to the discoveries are most frequently carried out for the sake of the knowledge itself, rather than from any intention of obtaining practical benefit. The background and foundation of the individual's character are to be explained in large measure from the degree in which he possesses different instincts. They determine in some measure what shall appeal to him and, in still larger measure, the amount of effort that he devotes to attaining the end that appeals.

**Race Instincts.** — No less important in the adult life are the race instincts. The mating instincts give illustration both of the definite but complicated response, and of the vaguer movements determined only as to their end, or even by the pleasure that comes from the attainment of a given purpose, with little control of the method of attainment.

The manner of the manifestations of the courting impulses is, in man, not at all a matter of conscious purpose. The display and boastfulness of the male on the one hand, or his bashfulness in the presence of a chosen member of the opposite sex, on the other, is in most cases not intentional, and cannot be prevented at will. The coyness of the maiden is equally removed from voluntary control. Even more widespread in their effect upon society are the activities and feelings involved in the care of the young and in keeping together the family. In man these processes are largely indefinite. They are guided by the pleasure of the parent in the welfare of the child. Most of the actual movements are learned through education and developed by habit. Only the pleasure produced by the achievement of the end and by the presence of the child is really instinctive; the rest is habit. In the lower animals of course the instincts are much more definite, as in the building of the nest, in determining the kind of food that is given, and the way it shall be given. Even here, however, much is left to the control of circumstances, for the processes cannot be reduced to a mere chain of reflexes. In man the continuous association and the care for the welfare of the members of the family constitute an important element in the development of unselfishness in general and of all the ideal elements in character.

**Social Instincts.** — The widest group of instincts, the social, are least often expressed as definite responses on the level of reflexes, and most frequently are merely goals imposed by feelings of pleasure or the reverse. The most primitive of the social instincts is simple gregariousness. This is shown in its purest form in the lower animals, but is not without its analogues in man. The bison or reindeer or the wolf, under certain circumstances, seems to feel

pleasure in merely being with others of his species. The same instinct may be seen in men who feel pleasure in being in the crowd on a city street, even if there be no words spoken and no intercourse of any kind with the members of the crowd. One may be absolutely alone, even avoid conversation with his fellows, and at the same time feel pleasure at their presence, or at least feel a haunting and unconquerable loneliness when away in the wilderness or where his fellows are not to be found. Obviously this instinct finds no simple expression in action, but is due merely to the pleasant feeling of being with others or to the displeasure of being alone. The individual may and usually does definitely plan the movements that will take him to a place where people are likely to be found, but the tendency to dwell fondly upon the idea is instinctive, as is also the restlessness that may persist without awareness of its cause until other human beings chance to come.

More active is sympathy which compels us to suffer with those who suffer even if we are jealous of those who rejoice. It is this that makes for self-sacrifice in all of its forms in behalf of those beyond the immediate family; it prevents cruelty on our own part and enforces giving aid to those who suffer at the hands of others or as the result of natural forces. It can be seen in the gregarious animals who exert themselves and even suffer in behalf of the herd, as the male deer are said to form a circle about the females and the young and to risk their own lives in defence of the unit. This instinct may be justified teleologically, since the survival of the individual and especially of the race depends upon the survival of the larger group. In man the most striking feature of the instinct is the limitation put upon the group included in its manifestations. It may and has been regarded as an extension of the racial instinct, the

instinct to protect the young, but it includes, with a force that diminishes with its extension, an ever-widening group of individuals. The members of the particular social set stand next to the family, then the individuals of the same class. The further extensions may include the ever-widening circle of political divisions, it may be drawn in some degree in terms of religious or party affiliations, — in fact, any common belief or common purpose may serve as the bond of union within which the instinct of sympathy may act. In these divisions any common ideal, particularly any common ideal that has opponents, may serve as the basis for the organization of a group within which the bonds of sympathy are effective against all outside it.

**Sympathy as Basis of Social Organization.** — These different lines of organization may cross in many ways. One's fellows in social position may be opponents in politics or religion, but the bonds of sympathy hold in one respect or within one group when the same individuals are separated in other respects. These groupings, with the consequent feelings, constitute the essential facts in any understanding of social organization. In the widest form, the instinct includes all individuals, and thus makes possible the highest development of civilization. Only in the actions called out toward members of the accepted social group is it possible to assert that we are dealing with an instinct. What shall constitute the group within which the instinct works is determined almost altogether by education and tradition. With mutual knowledge and increasing numbers of common interests the number of individuals that may be included in a social unity has grown beyond the bounds of any one country. But on the other hand, a widespread war will suddenly make rearrangements of this grouping, will put beyond the pale many individuals who have up to that

moment been most intimate members of some common group. The strong bonds between the socialists of all nations that existed before the Great War were suddenly broken by it. Thus, while instinct determines the treatment of the members of the common unit, education and experience determine who shall constitute the members.

**Social Pressure.** — Not sympathy only but a harsher set of repressing instincts also work within these social groups. The beginning of these is fear of strangers and the mass, which as bashfulness makes its appearance in early youth. This persists with varying periods of increase and decrease throughout life. This milder first form of fear as seen in bashfulness becomes in its more general expression the means of social discipline that makes possible action in the group. It can be seen first in the direct repressing influence of the group when physically present upon all but the leader, and on him it acts more strongly than he is willing to admit. One rises with fear, if at all, to protest against any action of a crowd. Unless experienced, a man shows many signs of fear as he addresses an unfamiliar, even if friendly, audience. The wider influence of the effects of this fear of social disapproval and pleasure in social approval can be seen everywhere in social affairs, and in many fields which are not usually recognized as social. It is social pressure which gives vital force to most ideals, religious and moral; and which compels us to follow styles in thought as well as in dress. One feels uncomfortable when clad in last year's gown, as one does when admitting adherence to an unpopular political party or to a generally condemned social theory. This is the real social pressure which compels conformity in every field. As an active force it drives the individual in much of his effort to get ahead. It keeps the student attentive to an uninteresting

lesson and it impels the laborer or business man to long hours of labor that shall enable him and his family to keep up appearances in their own social set or in that to which they aspire. These influences hold the man to his accepted place, keep him to his allotted task in moments of weariness, prevent eccentric acts and remarks, are the forces that make society possible, even if in very many cases they make convention dominate originality. In the individual they serve as spurs to many of the activities with a more remote purpose; they give the ideal and unselfish aim an approximation to equal standing with the material and the selfish.

### Instinct and Conduct

**Instinctive Conduct.** — We may look to instinct for an explanation of many phases of conduct which we cannot understand from the immediate circumstances or the earlier education of the individual. Through his instincts he is spurred to the avoidance of dangers that he does not know, is impelled toward the attainment of rewards that he cannot anticipate. Where he recognizes the goal and the purpose of the act, he is impelled, through instinct, to bodily reactions that he does not understand and which have no apparent meaning for the act itself. He trembles, he weeps, he smiles and glows with warmth, adjusts his tones to the mournful or the exultant key, all, so far as he can see, without reason. The insect lays its eggs and provides for the nourishment and protection of its young which in many cases it is never to see. In man the acts necessary for the propagation of the species are with more knowledge of the purpose, but nevertheless many of the details of conduct in that connection can be given no explanation from experience alone, and the strength of the impulses can be understood only from forces beyond experience, and often opposed

to reason. Balancing these in many respects are the social instincts which enlarge the circle of objects of instinctive acts and make the individual sensitive to the demands of the community with its laws and traditions.

**Instinct and Learning.** — It must be remembered throughout, that instincts never show themselves in isolation or in pure form. They are always mixed with the reflexes on the one side, and with habit and even with reason on the other. The distinction between reflex and instinct is hard to draw. Even when it has been decided that an activity belongs to the class of instincts, reflexes are always present to determine the execution of the individual acts. Almost if not quite all instinctive acts are also influenced by learning. Even so simple an act as the chick's pecking at a grain of corn is not performed the first time in full perfection and, in the more complicated processes, the instinctive and experiential factors can with difficulty be isolated. In one set of experiments the first attempts at pecking on the second day of the chick's life gave ten correct responses out of fifty. This increased to an average of a little less than forty by the seventh day, from which stage the progress was comparatively slow. While mere growth with age is important, practice is necessary in all cases, as is shown in experiments by Breed and Shepard. They kept chicks blindfolded for periods varying from birth up to five days and found that the number of correct reactions the first day of practice was no greater for the older than for the younger, but the older made more rapid progress. By the eighth day all were approximately on the same level, irrespective of the number of days of practice. In the more complicated acts of the higher animals, instincts are still more dependent upon training and habit formation. Birds kept in isolation do not ordinarily develop the peculiar song of their species,

but a new one. On the other hand, where young birds are kept exclusively with older birds of another species, they learn the song of that species within the limits of their own vocal capacity. Even the English sparrow will approximate the song of canaries if kept near them from birth. Heredity, it seems, provides nothing but the organs and the possibility of forming suitable connections, together with the tendency to use the vocal apparatus in any necessary way. All else is determined by the practice of the individual, guided by the sounds that are heard.

**Language Develops through Imitation.** — In man, instinct is still more mixed with habit and all the more rational and voluntary processes. Language is not instinctive as a specific process. As in the bird, what is instinctive is the organization that makes sounds possible, the instinct of making sounds, with no reference to the kind, and the desire for the approval of his fellows which makes a child desire to repeat the sounds. These together suffice to develop in the child the language of the people with whom it is thrown, by whom it is reared. Even the simplest instinctive acts are not performed at the first trial in their full perfection. Both practice and intelligent guidance are needed before great accuracy is attained. Here learning is hard to separate from the natural growth of the individual. The sex instincts appear in full vigor only as the individual approaches maturity. Other instincts come in part at least through the growth of the nervous system; they unfold one by one as the corresponding growth takes place. Still, it must be insisted that practice plays a part in the development of many instincts in man as it does in the pecking of the chick mentioned above. Furthermore, if the instinct is not used when it makes its appearance, there is some evidence that it may fall into disuse and fail to exhibit itself

later when occasion arises. Instinctive movements depend upon learning for their development, take on much of their specific form through practice, and, in some cases at least, disappear unless used.

**Imitation and Play.** — Specific instances of the way in which instinct and learning coöperate can be well illustrated by imitation and play, often spoken of as instincts. As a matter of actual observation we find that imitation in the life of man and the higher animals is very important. However, it is not possible to say that imitation is an instinct. The variety of movements involved is too great to bring it under the head of a complicated reflex, and, so far as one may regard it as a search for a goal determined by the pleasure of the attainment of the goal, nothing more is needed to account for it than the general instinctive pleasure of social approval. Thus, when the child learns to speak, it may be said roughly to be through imitation, but analysis proves that the child has an instinct to make sounds of no particular character. When by chance these result in words, the parents recognize and repeat, and give evidences of pleasure that lead the child to attempt to say them again; or the child may himself be vaguely conscious of the similarity of the sounds he makes to words that he has heard and so be more interested in them than in the other sounds. In any case it is the instinctive pleasure in sounds from others of his kind, and the approval they give to his own efforts, that lead to the repetition of the sound once made. Imitation in older individuals of movements that are already known in their elements can also be traced to similar general instincts.

**Play as Instinctive Expression.** — Play also is an expression of many instincts rather than of a single one. The tendency to play can be looked upon as a result of the

general tendency to action, to motor discharge. The character of the discharge, the particular form of play indulged in, is determined in part by the environment and by the general social instincts, and in part by a host of particular instincts. Thus, playing with a doll is partly imitation of the mother, partly an early budding of the maternal instinct; the hunting and fighting plays, the constructive plays, all forms of rivalry and competition, are but the exhibition of different instincts under make-believe conditions, under circumstances assumed to exist for the sake of the play. At most, play is no single instinct but the expression of a host of instincts under the pressure of a general tendency to act. It is an outlet for a reserve of energy under the effects of stimulation. The value of play in developing capacities through practice in advance of the actual necessity is obvious.

## The Origin of Instinct

**The Rise of Instinct.** — The origin of instinct is primarily a problem for the biologist. Instincts are nervous dispositions that have been developed in the different species and are then inherited. The way in which instincts might arise has attracted most attention, as the inheritance is largely taken for granted. The opposing general theories of evolution — the theory of acquired characters and the theory of natural selection — have been applied to its explanation. For psychology either theory suffices. It would be easier to explain instinct as the inheritance of the tendency to make movements that have been repeatedly made by the ancestors, but a great many biologists are at present sceptical of the possibility of such an inheritance (the inheritance of acquired characters), and psychology has no evidence of its own to offer in its favor. It is certain

that no specific acts which have been developed in a high degree by the father exhibit themselves in the child; and when any particular capacity of the father can be detected in the child, it is doubtful whether it is not due to the inheritance of the father's innate characters, rather than inheritance of his training. Barring inheritance of acquired characters, instincts must be due to the selection of the individuals who chance to develop tendencies to responses favorable to survival. The cause of the change in the germ plasm that produces the favorable instinct is not at all determined. It may be due to some chemical action, as in some cases it has been shown to be induced by physical stimuli; but given the change, however it arises, it tends to persist in the later generations. All that the doctrine of natural selection asserts in addition is that those organisms which chance to develop tendencies to action favorable to their survival and to the continuance of the species will increase in numbers, and those which fail to develop this tendency will die out and their instincts will die with them. As a result of this selection in the course of the ages and innumerable generations of individuals, we find man a being provided with many of the structures essential to his present method of living, as well as many that are left over from stages in which they may have been useful, but which are now at best not harmful. Similarly, selection has given a nervous system with connections and predispositions that are on the whole adequate to the direction of the bodily structures, although there are some, those at the basis of many of the fears, for example, that might easily be dispensed with.

In conclusion, we must assume that a number of the most fundamental reactions and demands of the organism are present in it from birth and serve as a foundation for the superstructure of learning. In part these are specific acts

or groups of acts, in part they make their effect felt as ends towards which the organism must struggle by whatever movements it may have at its disposal. There seems to be a possibility of making either the movements that are aroused through instinct, or the feeling that accompanies the movement, fundamental in the explanation of all instincts. In the one case, each situation would call out a definite response, and, where the obvious response was lacking, it could be assumed that it was still present in some obscured or unnoticed form. On the other hand, it might be assumed that it is the feeling which is instinctive, — the pleasure that accompanies the instinctively determined proper end, and the unpleasantness or restlessness that persists until that end is attained. As has been seen, one theory would hold very satisfactorily for one type of instinct, the other just as satisfactorily for another. It seems more in harmony with the facts and, on the whole, to offer less difficulty for the theory, to assume that both the movement and the feeling are accompaniments or results of the single biological predisposition. At the lower level the movement, at the upper levels the end which asserts itself only because it is pleasant when attained, are the more frequent characteristics of the instinct. This leaves much to be explained, but it does permit the use of the word in the broad sense, implied if not explicitly adopted, by modern psychologists.

In instinct we find the source of most of the movements and many of the feelings which we cannot explain by immediate stimuli or from the earlier experience of the individual. It not merely provides the germ which is later developed into the complicated movements, but also many of the strongest incentives that we have in connection with our most complex voluntary and rational life. If one ask why

one is afraid of the dark, why the mysterious thrills, the answer can be given only in terms of instinct. Similarly, if one ask why acquiring wealth, or inventing a new machine, or discovering some new truth, should be of almost universal appeal, we can again reply only that they are instincts. If one seeks the reason for falling in love, and for many of the actions, particularly of the thrills and blushings and tones peculiar to that state, one must look to instinct. Finally, and most important of all, the social instinct supplies the desire to be popular, to seek the approval of companions, upon which depends the force of social convention, and which drives to work when individual need and individual instinct exhaust their impelling power. If this extreme statement would seem to make everything worth while only because of its instinctive appeal, it must be remembered that instinct is developed, modified, and even restrained through experience, and reduced to conventional type by social pressure, itself an expression of the social instinct. Certain it is that very many of the phenomena in connection with feeling and action and particularly in emotion can be understood, if they are to be understood at all, only through instinct.

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# CHAPTER VIII

## RECALL, AND THE QUALITIES OF RECALLED EXPERIENCES

NOT all of the material of knowledge comes directly from the sense organs. Memory, imagination, and similar processes have an equal part in our mental life. From the objective point of view, behavior is controlled by the past as well as by the present stimuli. Provisionally we may recall and use memories as if they were on the same level as sensations. We may think of them as composed of definite pictures which return as wholes or are recompounded of elements derived from the senses. We must seek to determine their components, and to discover how they are retained, and the laws that govern their reappearance. The primary qualities are like sensations. No absolutely new qualities can be imagined. Speaking generally, the qualities of memory and imagination are the qualities of sensation. It is possible to go farther and assert that if one is to have in mind images of a given quality, one must at some time have had sensations of the corresponding quality. Individuals blind from birth cannot imagine colors; even the color blind cannot picture the colors which they cannot see. The same holds for all other senses. This has led to the general acceptance in modern times of the statement that all images are derived primarily from sensations. This simplifies our discussion to an investigation of how the original impressions are retained, how they may be rearoused as occasion demands, and how their qualities differ from those of the original.

## Retention

**The Nature of Retention.** — Before asking how memories are retained we must inquire where they are retained. Two possibilities have been suggested in the history of the science: one that they are retained in mind or as mental states, the other that they are held in the nervous system. The latter view is at present generally accepted. The theoretical objection to thinking of memories as retained in the form of mental states is that mental states are by definition conscious, whereas actually there is no awareness of memories until they are revived. The individual cannot tell that he has a memory, until he tests it by trying to call up particular facts. On the positive side, the evidence that remembering is in some way dependent upon the nervous system comes from pathology. Numerous cases present themselves in which loss of memory is one of the prominent symptoms, and these usually show, on examination of the brain, injuries of portions of the cortex. Destruction of the area corresponding to a sense brings with it loss of the corresponding memories; destruction of neighboring areas or of paths of connection with other portions of the cortex also destroys or impairs the effectiveness of recall of the images. Studies in mental pathology have convinced psychologists that memory processes are closely dependent upon the nervous system.

The methods of retaining memories offer more room for discussion. Various theories have been suggested, from the crude theory of the Greeks that memories were imprinted on the brain or soul, as the impression of the seal upon wax, to the scarcely less crude anatomical theory that each idea has a cell in the brain in which it may be stored. At present the tendency is to find analogies that shall be

within the known possibilities of the nervous system, and not to make the explanation more specific than the known facts warrant. The explanation is usually in terms of function, of what the nervous system does when it remembers, rather than of the manner in which it holds the memories. Hering was among the first of the modern writers to suggest this method of approach, in stating that memory is a universal property of matter. Any change that may be suffered by any substance tends to persist. Garments wrinkle where they have been often creased; for example, the folding is 'remembered' by the garment. Scars on the skin, even nail holes in boards, are memories, according to Hering, effects left on the substance by changes it has undergone. In the organic world similar facts are particularly striking. The physician constantly finds that any injury or disease of a tissue leaves an effect, — it is weakened for a considerable time. On the other side, exercise of a muscle strengthens it.

**Retention and Habit.** — Habit is the best known expression of this fact in its relation to the nervous system. As was said in Chapter VI, habit may be defined in its most general form as a change induced in a tissue as a result of some act. This leaves a tendency to do that same thing more easily. Signs of habit formation may be seen even in the unicellular organisms. A Stentor responds differently after a series of responses have failed to give a pleasant result; and after the new variation has been repeated several times, it tends to persist for some time, too, — becomes a habit. In the higher organisms one may think of both habit formation and of memory as due to persistence of changes wrought in the nervous system by its action. Habits are regarded as due to changes in the synapses of the nervous system. Neurones that have acted together once,

tend to act together again; nervous impulses spread from the one first active to the others, owing to the lessened resistance of the synapses that intervene. From the standpoint of Hering, memory in its essentials has the same basis. It is primarily the capacity of retaining the effects of one action of the nervous system in a form that shall make probable its repetition at some time in the future, rather than the retaining of some static thing, or impression, or idea. Speaking generally, after an object has once been perceived, a tendency persists for the neurones involved to act in the same way again, and this tendency leads to the revival of the image on suitable occasions. The nervous system may be regarded as acting in a certain way at the time of perception, and of repeating approximately the same action at some later time. Those portions of the cortex which are concerned, become connected as a unitary whole, and when one part is reëxcited, the others are rearoused. What is left is merely the physical or chemical change in the neurones. Where this change takes place, can be determined only by indirect means. Present evidence makes it probable that the most important part of the change is found in the sensory areas or in the immediately adjoining association areas, although no portion of the original nervous tract can be absolutely excluded from consideration.

**After-image, Memory After-image, and Memory Image.** — One may also trace an analogy between memory and simpler forms of retention or prolongation of activity in the sense organ. In vision, gradations may be traced between the after-image and the memory image. If one look for a moment at a bright color, the sensation will probably last for a fraction of a second after the impression has been removed. Even faint objects leave a second image, clearer

and of longer duration than the first, which does not move with the eyes, and may be shown to have its seat in the cortex. This process is known as the primary memory, and is probably partly identical with what Fechner called the memory after-image. It is sufficiently distinct to be used for all purposes in place of the actual sensation, and is for many purposes even more effective than the sensation. It may be regarded as due to a persistence of the activity of the cortical elements involved in sensation in just the same way that the after-image is a continuation of the action of the retinal elements. The cortical cells have even greater inertia and so act for a longer time than the rods and cones. A memory, on the same analogy, is merely the reinstatement of the primary memory image after the lapse of a longer or shorter period. The same nervous elements may be assumed to be active at the moment of recall as in the original stimulation, but they cease to act or at least cease to produce conscious processes for a longer or shorter time, and then the activity is in some way reinstated. The three — after-image, memory after-image, and memory image — all exhibit many of the same laws, and may be regarded as succeeding steps in the same series. The after-image is the persistence of the effect in the sense organ; the primary memory, a persistence of the activity of cells in the cortex; memory, a reinstatement of the activity in the cells of the cortex involved in the primary memory.

**Perseveration.** — Granted the existence of a tendency to act again in a way once acted, it is next in order to ask how or when this reinstatement of the activity may take place. Two occasions are ordinarily recognized at present, — the perseverative tendency, and association. The former is simpler, although less frequent and less generally accepted. It was suggested by Müller and Pilzecker that, when an

impression has been made, the nerve cells impressed continue active for a time, and in consequence, the corresponding ideas are likely to force their way into consciousness when nothing else offers, or to combine with other processes active at the same time in the production of more complex processes. This they call perseveration. Instances mentioned are the reappearance of words that have been heard or spoken just before, but have no noticeable connection with the course of thought; the tendency of tunes to 'run in the head'; of complicated practical problems to keep returning to mind on all occasions, etc. This tendency seems to decrease rather quickly at first, but some slight effect apparently persists for hours, and when the original event is interesting or the impression strong, may last for several days. It is assumed that the activity of the nerve cells is continuous, but that the effect of their activity rises to consciousness only now and again. While the perseveration tendency itself is unquestioned, it is a matter of dispute how long it continues and whether the reappearance of the experiences after a little time are due to it, or to associations that have not been noticed.

## Association

**Laws of Association.** — Association as an explanation of recall can be traced back to Aristotle in fairly accurate formulation, and approximations to it are found in still earlier writers.[1] In one or another form it is recognized by all. In

[1] Closely related in meaning to association is the word *suggestion*. Suggestion, too, is used to designate the recall of one idea by another. Since, however, suggestion is also used for the evocation of a movement by an idea, and particularly because it has been applied very generally to the arousal of ideas and movements in hypnotism and similar more or less abnormal conditions, the psychologist usually avoids the use of the term in connection with the normal processes.

general, this doctrine asserts that all reproduction of ideas is determined by the connections that have been formed at some time in the past. Conversely, mental processes which have once been in consciousness together, tend to return together. An empirical study of learning shows that words, nonsense syllables, or objects shown together or in immediate succession, tend to become connected and, when one is presented again, the other may also reappear. Learning the name of a new object, connecting a person with a place where he has been seen, all rote learning, are instances of this fact. On the physiological side, it may be said that all learning, all experience, is of things in their connections, and that all return is through the connections formed between neurones at the instant of learning. When a group of neurones is active at the time of the original experience, paths of connection are formed, synapses are opened between them, and, later, when any element of the complex is aroused in any way, the impulse tends to spread over the partially open synapses to the other elements of the whole. Association has the same basis as habit, but need not end in a muscular response. As was said in the beginning of the chapter, all learning is like habit formation; all learning is dependent upon formation of connections between neurones, — nothing can be learned in isolation. In consequence, association is at once the fundamental fact in learning, in retention, and in recall. Learning is always the formation of connections between neurones; retention is always the persistence of the connection, or the partial openness of synapses which permits an impression to pass from one to the other of the connected elements; recall is the rearousal of the whole complex by some one of the elements that may be stimulated from the outside world, directly or indirectly.

While from the standpoint of learning it may be asserted with assurance that impressions presented together tend to return together, more complication appears when one attempts to determine what it is that brings any particular old experience to mind. Any idea that returns has almost always been associated with several, often with many, experiences; and it is difficult to say which one has been responsible for its recall. In fact, a number of factors more or less remote usually coöperate in the recall. Similarly, if some one familiar experience be presented, it is not possible to say with certainty what idea will be recalled by it. One may study the tendencies to recall, by presenting a number of words to a subject, and letting him speak the first word that comes to mind. If the same list of words be presented to a number of persons of approximately the same earlier experience, it is found that a large number of the responses will be common to all. Kent and Rosanoff secured the associations called out in a thousand people to each of one hundred words and found that the number of common words was very large. Thus to *man*, 394 responded *woman*, 99 *male*, 30 *strength*, 44 *boy*, 30 *person*, etc.; to *mountain*, 246 responded *high*, 184 *hill*, 73 *height*, 90 *valley*; to *soft*, 365 responded *hard*, 53 *pillow*, 34 *easy*, etc. If one will permit the train of ideas to wander uncontrolled for five seconds and then write down the ideas that present themselves, similar connections can be traced. The connections have from time immemorial been classified under four heads, — contiguity, succession, similarity, and contrast. In our list of words it will be seen that all the connections given can be traced to one of these groups. Soft and hard, mountain and valley, man and woman, may be regarded as contrasting; hill and mountain, soft and easy, man and male, may be regarded as similar; soft and pillow, high and

mountain, man and strength, as connected through verbal succession or by contiguity of the objects.

It should be noted that this is a classification of the connections after they have been formed, and is made after rather than before the fact. It is a classification of the relation the ideas hold to each other, rather than a statement of the causes of recall. Even so far as it holds, it is not altogether unambiguous. Mountain and valley are contiguous as well as contrasting, man and woman, as all contrasting things must be, are in some degree similar; they also are frequently found together and the words have been repeated in succession. For the real cause of arousal, we must turn again to the neurones that are involved in the activity.

**The Nervous Basis of Association.** — A new method of forming connections in the nervous system seems to be implied in the association process. Hitherto, all of the connections studied have run from the sensory to the motor neurones; and the synapses that open are those that are traversed by the impulse. In association the connection is formed between two groups of sensory neurones and between groups of neurones not on a single sensori-motor arc. Thus when a child is shown an object and hears the name spoken, the sight of the object excites a region in the occipital lobe; the name heard arouses the auditory area in the temporal lobe. These areas are widely separated on the cortex, yet nevertheless after frequent recurrence of the excitations, a connection is formed between them of such a character that when the object is seen the name is thought, and when the name is heard the image of the object is reinstated. Two theories have been held to explain the way in which the path is formed. One is that the path is established indirectly through some common pathway of

motor discharge. It is implied that the sound heard would lead to an attempt to repeat it, and the object seen would lead to the same response, and that all that would be needed would be to cross-connect the two sensory areas. This, it might be argued, again could be established indirectly by a backward opening of the path from the motor response to the sensory stimulus not previously evoking it.

**Association as Conditioned Reflex.** — This form of association is what Watson has called the conditioned reflex on the motor side. It is well typified in the dog which produces a salivary secretion, — ordinarily induced by the sight of food, — in response to the sound of a bell that has been frequently sounded at the same time that the food is seen. Similarly when a child is shown a cat at a time when it is indifferent to cats and at the same time a bell is sounded loudly enough to startle it, the withdrawal that comes with the bell is gradually transferred to the cat. Three objections may be raised to the assumption that the motor response is at all necessary to the formation of the connection. In the first place, the two motor discharges ordinarily run towards the same outlet, but with no lines of communication between them. In the second place, to assume that the path is formed along the lines of motor discharge means that the impulse runs from motor to sensory neurones. In the third place, connections of this cross character are formed when no noticeable movement results. These considerations make it necessary to assume that both for motor cross connections and sensory associations direct paths must be opened by the simultaneous activity of parts of the nervous system.

**The Law of Drainage.** — The general assumption is that any two regions active at the same time either as parts of two sensory excitations or of two sensori-motor pathways

tend to have paths opened between them. This is what McDougall called the 'law of drainage,' for he argued that whenever two parts of the cortex are active at the same time or in immediate succession the neural excitation of one tends to drain over into the other. This term 'drainage' is perhaps an inadequate picture, as the nervous discharge is very sudden, although there is the long-drawn-out-after effect of perseveration, during which something like drainage may go on. However it be imaged, there can be no doubt of the fact that simultaneous activity of two parts of the cortex opens a path between them of such a character that whenever the one is aroused at a later time the other also tends to be aroused. The more frequent the repetition of this common excitation, particularly when the excitation later spreads by association from one to the other, the stronger is the tendency for one to arouse the other.

One fact that limits the generality of this statement is that not all elements that are active simultaneously become so closely connected that one actually will recall the other. Only those elements which for some reason have something in common seem to be firmly united. Those that are attended to together, those which lead to a single act, those which are particularly intense or are accompanied by a strong emotion are strongly associated. Of these cases, the only one that would give any evidence of the occasion for selecting one element rather than another in forming an association is that they lead to a common act. This as stated above is not really a cause, since they lead to the common act as a result of their association, rather than becoming united because they both excite the same movement. At present then we can go no farther in our explanation of how these neurones become associated than to assert that when two groups of neurones in any part of the

cortex are strongly excited at the same time or in close succession, a path is opened between them, and thereafter whenever one is excited the other tends to be excited also.

**Physiological Classification of Association.** — The cause of the permeability of the synapses may be made the correlate of either contiguity or of succession. The former is the simpler, as it is an expression of the law that two elements active together once, tend to act together from that time on. Succession has practically the same explanation. The second neurone begins to act before the first ceases its activity, and so the two actions of the neurones are simultaneous. If similarity is to be explained in physiological terms, it must be reduced to partial identity. What one calls an idea is always complex and may be pictured as corresponding to the action of a number of neurones. In what is classified as association by similarity, a mass of neurones corresponding to the first idea are active, and as time goes on, parts of the group cease to be active. Only the one group that corresponds to the part of the idea most attended to at the moment persists in its activity; and from this, new neurones that correspond to the elements of the second idea are excited by virtue of their previous connections with the persisting portions of the first. On the side of consciousness, many 'ideas' in the popular use of the term are complexes of experiences, complexes of sensations; probably also the action of many different neurones is involved in their appearance. In the recall of any complex idea, these different elements probably enter into many different combinations, and the effective connections are between the elements, not between the larger masses. Thus when an idea recalls another similar one, the similarity is due to some common element, and this common element may be regarded as persisting from one idea to the

other. In one idea, everything disappears except the elements that are common; these persist and gather about them by association the other elements which with them may be regarded as constituting the new idea. When the ideas are classified afterwards, they are seen to be similar, the association is said to be by similarity, but the effective forces have been the waning of certain elements of the first idea and the excitation of others by those remaining. Association by similarity is really through partial identity, and the identical element furnishes the bond of connection.

**The Limits of Association.** — Not only must we limit the application of the doctrine of associations by the assertion that it is the neurones at the basis of the elements of ideas that are associated rather than the ideas themselves, but we must also recognize that associations give only the possibility of recall, and that selection from the possible associates must be made by more remote factors. Most neurones or sensory elements have been connected at different times with several other elements, and may be regarded as having a tendency, whenever any one is aroused in any way, to rearouse each of the others with which it has been connected. Which of the possible elements shall be aroused is determined by the same elements that control attention. A discussion of these may be postponed to the next chapter. For the present we may say that the return of an experience or the renewal of an excitation of a group of neurones depends in some degree upon the continued activity (perseveration) of the elements in question, an activity that lasts for a relatively short time, but for the most part depends upon the fact that when any two groups of nerve cells have been active together at any time and one is reëxcited, that excitation tends to rearouse its earlier associates.

[redacted]



## Images, or Centrally Aroused Sensations

**The Qualities of Centrally Aroused Sensations.** — These memory processes may be studied, not merely to determine the ways in which they are retained and the laws of their revival, but also with reference to the actual content that they offer. One may study the materials of the remembered impressions just as one may study the qualities that are derived from the external senses to determine the elements that make them up or, more profitably, to compare them with the qualities of the immediate sensations.

Most untrained individuals do not notice the content of their minds as they recall; they are content to know that they recall an object and can describe it. Others who have had training in introspection find that they do not have images; they have no definite mental content when they recall an object but have merely the certainty that they have seen it before. Our present problem is to determine what is in mind when the object is recalled. If one is attempting to recall a desert or a mountain landscape seen years ago, for example, one may either repeat words that have been associated with the experience without any definite picture of the landscape, one may have fleeting bits of yellow sand or snow-covered peaks with many vacant areas or dark gray regions with no definite pictures, or one may have a clear and distinct picture from which one may paint or describe many if not all of the details. Our question at present is how these images differ from individual to individual, and how they resemble, and how they differ from, actual sensations.

Two methods of investigation have been applied to the solution of this problem. The first of these was used by

Külpe[1] in an experiment to determine how one might distinguish faint sensations from imagined or remembered experiences. Faint sensations were chosen because memories are generally believed to be fainter than sensations. Investigators were placed in a dark room where faint lights of different colors could be thrown upon the wall. At a given signal, the observers were asked to say whether a light was seen and then, if it were seen, to say whether it was objective or merely imagined. At times a light was really shown, at others not. In most cases at the signal the observers either saw or imagined a color. After the report had been given, an attempt was made to determine what differences were used as a basis of deciding whether the image was really seen or only imagined. In this, observers varied. All agreed that there was a constant difference in quality. The imagined colors were more transparent, were net-like or clouded. The sensations seemed brighter, they entered and left consciousness suddenly and as wholes, had a more definite form, were clearer, and were given a more definite position in space. They were distinguished also by the more active tests, — that sensory colors left an after-image, were stationary when the eyes moved and vanished on closing the eyes, — while the reverse held in each particular for the imagined processes. In addition there were individual peculiarities from man to man; for example, greater duration was given by one as characteristic of sensation and by another as characteristic of the image. The results of this investigation indicate that characteristically different qualities attach to the processes aroused through association which distinguishes them from the real sensations.

**The Projection of the Memory Image.** — Another in-

[1] Külpe, Philosophische Studien, vol. 19, pp. 508–556.

vestigation gives approximately the same results by a method even more striking. Miss Martin[1] found that it was possible after a little practice to project a memory image outward into space, where it might be more readily compared with sensations. The different location of images and sensations serves in our ordinary experience as one criterion for distinguishing them. We refer perceptions to the point where the object is assumed to be in the outside world, while the memory or imagination either is given an indefinite place, is projected backward within the head, or possibly referred to the place where it actually is, but usually is not seen upon the surface that is actually presented to the eyes. Miss Martin's observers found it possible to bring the image and the object side by side. When the difference in projection that ordinarily exists between images and perceptions had thus been removed, it was found that there were still characteristic differences between the two in their coloring, in definiteness of contours, in clearness, intensity, and stability. The sensations had the advantage in each of these respects. One other characteristic is the relation to the movements of the eyes. While in these experiments the images did not always move with the eyes, there was always a tendency to movement when the eyes moved that could be avoided only by considerable strain. All of these criteria for distinguishing between the two agree with those indicated by Külpe's investigation. One other presents itself for certain observers, — that is, the tendency to see the images in front of the background of sensory objects which may be present. The background may be seen through them as through a veil. In general it is noticed that sensory impressions interfere with the

[1] Martin, Die Projektionsmethode und die Lokalisation visueller und anderer Vorstellungsbilder.

perception of other objects, while images do not thus interfere.

Individuals who possess definite images, then, have also characteristic means of distinguishing them from the sensations. The images are sufficiently different from the sensory experiences to prevent one from being mistaken for the other. Individuals frequently fail to notice the characteristics that serve to distinguish images from sensations. In fact, few make this distinction until it has been called to their attention; but the differences serve to ascribe the process to the world of things if of one character, or to the world of memory and imagination if of another character. In addition to these differences in the mental content, the connections in which the experiences present themselves also play a part in determining whether an experience is objective or subjective. If the object or event follows naturally upon other events that are recognized as objective, if the sound of steps is heard outside, the bell rings, a servant answers, and a moment later a friend enters the room, there is no question of the objectivity of the experience. If, on the other hand, a letter in a familiar handwriting is seen and then an image of the friend who wrote the letter appears, there is no doubt that the image is subjective. One event fits into the world of things, the other into the world of memories, and in consequence the one is assigned to the one group, the other to the other. This placing of the mental process in terms of antecedent events and the setting is undoubtedly the most important of the factors that lead us to discriminate between the objective and the subjective. Again this operation is not noticed for itself. One knows at once that one sees an object in the one case and that one merely remembers it in the other. The method of remembering is no more noticed

than is the method of perceiving. That it is necessary to make the distinction is seen from the fact that in hallucinations and in dreams mistakes are made. The processes aroused by association alone are referred to the real world and are treated as objects.

## Imagery Types

**The Materials of Memory and Imagination.** — One may in a degree and for most individuals parallel the sensations which are regarded as constituting the raw material of our external experiences by a series of images or centrally aroused sensations which constitute the materials out of which the things that appear in memory, imagination, and reason, are composed, 'the stuff of which dreams are made.' These are retained in the central nervous system and re-aroused by stimuli that have been connected with them in the past and by other ideas that have been experienced with them. It should be noted that the memory images are usually not so complete as the sense presentations, that even the clearest of them have large gaps due either to imperfect attention at the time of perception or to lack of interest in some phase at the moment of recall. Also much of our memory and thinking is not in definite reproductions or constructions of the objects, but is very sketchy. It is very frequently in words or in some other symbol that represents or means the thing rather than a reinstatement of the elements which actually constitute it. This must be considered in detail later on; it is mentioned now merely as indicating that our inner mental life is not to be described completely in terms of definite images. Even where centrally aroused sensations are most definite, the number of qualities is less than the number that may be found in immediate sensation. Of the hundreds of grays, the un-

practised man cannot recall more than a dozen. Relatively few elements in memory must be made to do duty for the vast number of sensation qualities.

**Memory Types.** — In our discussion of the qualities of the centrally aroused processes, it must be noticed not only that the quality of the memory element is not the same as the quality of the thing represented, but the way in which anything is recalled differs greatly from individual to individual. We all think of the same things, but probably no two of us have in mind exactly the same images when we think of the object. The main differences in representing objects and events can be most readily stated in terms of the sense organ or the sense material that is emphasized or drawn upon by the individual. The students of mental disturbance, Charcot among the first, noticed that certain men would make predominant use of the visual memories, others of the motor, others again of the auditory. Still later Galton[1] made a careful examination of the way a number of individuals recalled the breakfast table, with the result that some were found who would merely recall the way the dishes and the people at the table looked, others could remember the sounds of words and the rattle of the utensils, still others could remember only how their own various movements felt as they were made. More rare were the individuals who could remember the odors and tastes of the food, and these memories were usually indistinct and subordinate. Galton also distinguished the verbal type, individuals who recalled everything in words, either as words seen, or words heard, or words as they would be felt in the vocal organs at the time they were uttered. In older individuals, particularly men of science and others who indulged much in abstract thought, the

[1] Galton, Inquiries into Human Faculties.

verbal tended to predominate over the more concrete imagery.

Galton or certain of his expositors give the impression that an individual is likely to have one type to the exclusion or at the expense of all others. Certain of the later writers have still more exaggerated this assertion of the mutual exclusiveness of types. Stricker, for instance, has argued that every one must be of the motor type, and further that the recall consists in nothing more than the reinstatement, in some slight degree, of the movements made on a large scale at the time of the original experience. He challenges any one to think the sound of *o* with closed lips, and regards failure to do so as proof of his contention that all thinking is in terms of a reinstatement of some movement. Most recent investigators, however, incline to the view that, while imagery is much more restricted than sensation, most individuals have memories from more than one sense, many from two or more in approximately the same degree. These latter individuals will use the type of imagery most suited to the problem in hand. If, for example, one both paints and composes music, one would plan a picture in visual images and compose in musical tones. While one or more types may be lacking in most individuals, and one or more be preferred, the sharp classification into visual, auditory, etc., seems too rigid to harmonize with the facts.

**Verbal Imagery.** — Two major forms of imagery may be distinguished, the verbal and the concrete. They are not mutually exclusive in any sense, as most individuals will use the verbal in more abstract thinking and in cases where they must describe the event and will use concrete images on other occasions. Words may be presented to one's self in three distinctly different ways.

First, by revived kinæsthetic impressions, the sensations that come from the vocal organs when the word is spoken are revived in memory. This may, in certain individuals and at times in all, take the form of the slight movements of the vocal organs that were mentioned by Stricker.

Secondly, in revived auditory sensations of the words as they might be heard when spoken by one's self or another.

It is also possible to recall the words as they would look on the printed page. This visual recall is not frequent as an antecedent of speech, but where one attempts to recall letters or figures it may predominate. It will also be used when one is listening tc a language more familiar in reading than in speech.

**Concrete Imagery.** — In concrete imagery any one of the senses may predominate and several may be used simultaneously. Professor Griffitts, in an unpublished study of the imagery of more than one hundred students, found that more than ninety per cent relied mainly upon visual imagery. Next in order of importance were auditory and motor, with less than five per cent of each. Even these, for the most part, used vision when recalling concrete impressions, but made large use of verbal imagery. Only one man was found in one hundred and twelve cases who had no visual imagery. While there were only very few who were confined to one sense in recall, there were great differences in the degree of clearness of the different forms of sensory imagery. Some individuals recall and imagine events visually with almost the vividness of real objects. Others have very indefinite images, which suggest rather than reproduce events. There is a marked difference between dominance and definiteness of imagery. Certain in-

dividuals who use almost no imagery but visual, have less vivid visual images than others who are predominantly auditory or motor, and have only secondary visual memories. Another indication that imagery is not exclusively of one sense is the fact that individuals with well-developed auditory imagery also are likely to have vivid visual imagery. One cannot speak of types, as the older men did, with the implication that if one has a well-developed imagery from one sense, one is likely to be defective in others. Rather, it is true that men differ in the sense that they use most frequently in memory and imagination and also differ in the vividness or effectiveness of the sense that is dominant.

**The Origin of Imagery Types.** — The differences are probably due in part to heredity and in part to training. Evidence may be adduced by a few cases in favor of a hereditary predisposition. Dodge, who is almost altogether without auditory imagery, reports that his parents had the same lack. The inheritance of musical ability, which in all probability depends upon the possession of auditory imagery, may also be cited as evidence of a hereditary tendency. On the other side, training has been shown in several individual cases to have exerted an influence in changing the memory type. Particularly with school children, it is found that they can be trained to considerable facility in types of imagination in which they possess no natural skill. Even in adults long practice gives results in the development of new forms of imagery. A student who cannot spell because he cannot see the words in his mind's eye can by repeated effort bring himself to visualize the words, with some degree of improvement on the practical side. It does not follow, however, that spelling is absolutely dependent upon the possession of the visual type.

It seems, then, that both heredity and training may play a part in determining the mental type, — certainly training may change what is given by heredity.

**Synæsthesia.** — A curious occasional phenomenon is the close connection in certain individuals between objects or sensations of different senses. Numerous cases have been recorded in which letters have colors closely connected with them in the mind of an individual: *a* may be pink, *o* green, etc. Words also either have a color of their own, or take on the color of the letters that make them up. Several cases have been reported, too, in which musicians have colors aroused by certain tones or tone combinations, and these may seem to be essential components of the tone effects. Thus Myers reports that Scriabin, the Russian composer, had a different color for the different keys. The major keys of C, D, B, and F# have the colors of red, orange-yellow, blue, and violet, respectively, and the effects are so strong that he desired to have his compositions rendered to the accompaniment of colored lights that should flood the hall from concealed lamps. In another striking case odors were associated with colors; in fact, were often only perceived through their color associations.

Two theories have been held to account for the phenomenon: one that the connections have been made through association, the other that it is fundamental and perhaps due to the fact that there is some common feeling or other element which serves to connect the two sensory components. The second theory, if true, must admit that individuals who possess this idiosyncrasy seldom agree as to the colors that shall be associated with a particular tone, although each person who has it feels that it is universal and necessary. The association theory is as

yet equally unproven, although a few characteristic peculiarities suggest that the connection of colors with letters or tones may be due to old habits. Thus in three sisters whom I investigated, one of the few correspondences was that *j* was said to have a gritty brown color to all three, an obvious connection with jug. How far heredity plays a part, how far there may be more fundamental common characteristics between the sensations connected, and how far the phenomenon may be merely the result of early associations is still largely a matter of conjecture.

In brief, the qualities of memory and imagination are the same as the qualities of sensations, a little less numerous, with not quite the same distinctness, but with no new qualities added. These impressions are recalled through laws of association not so very different from the laws of habit, and are woven together in new patterns to give features of remembered events that suit the purpose of the moment, or to make new constructions of imagination or reason. As is to be seen in the next chapter, these constructions are subordinate to more general control in the same degree and by the same laws as sensations.

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# CHAPTER IX

## ATTENTION

So far we have been tracing the influences of the environment, of past experience, and of evolution and heredity, in determining the actions and the mental states of man. These provide the materials of mind and the basic tendencies of action. One other characteristic of consciousness and action must be discussed. This is the fact of selection which is known both popularly and by psychologists as attention. The stimuli that affect the sense organs do not exert an influence directly proportional to their energy or to the frequency with which they have been repeated. Certain stimuli will produce an effect at one time that they will not produce at another. A faint stimulus of a certain kind will have a greater effect than an intense stimulus of another kind. This difference can be seen both in the movements that are excited and by the fact that one will affect consciousness, the other not. This fact of selection must itself be given an explanation. We must determine the laws under which selection takes place and if possible trace the changes to their causes.

### The Nature of Attention

The fact of attention is apparent to every one and at all times. As one looks out over a landscape, one feature after another is noticed; as one sits at the study table working, the noise of the street, and memories of all kinds, will from time to time intrude themselves and crowd out the page of

the book, even if the eyes still wander along the lines of print and all the other physical conditions of reading are unchanged. In both cases the mental content varies because of changes within rather than without the body. We are conscious at any time of only a fraction of the things that might be observed. Many sensory experiences pass unnoticed unless we look for them particularly. The vast majority of objects presenting themselves to the eyes are not seen, and many of the sounds that fall upon the ear are not heard. Only the few that appeal to us at the moment are selected.

Consciousness as a whole has been likened by Wundt to the field of vision. There is a point of clearest vision in the centre where the cones are very close together, and a gradually decreasing clearness as one passes outward to the circumference. The point of maximum attention corresponds to the fovea in the field of vision, the other regions of consciousness to the periphery. Attention may wander over the field of consciousness in much the same way that the eye wanders over the field of vision. The common characteristic of foveal vision and attention is the increased clearness that comes in both cases. As a result, contours and differences in intensity between parts are better discriminated. Temporal effects of attending to a sensation have been noted in hastening its entrance and in keeping it a little longer in consciousness. All these differences would increase the importance of the impression attended to as compared with one that is not attended to.

**Does Attention Increase the Intensity of Sensation?** — What change does attention bring about in the content of consciousness? The answer is to be found in the observation of one's own state as one attends, rather than in a verbal description. Certain it is that the object or event

attended to becomes in every way more important for consciousness; it stands out above the others at the moment, is also more likely to be remembered and to start new trains of thought. The character of the change can be given only by comparing it with other known changes and indicating the similarities and differences between them. In many respects it is like an increase in intensity. Increase in the intensity of a physical stimulus also make it more likely to affect consciousness, increases the probability that it will be remembered, and quickens the reaction to it. That attention and increase in intensity are not identical is evident from the fact that we never mistake one for another. We never assume that a sound has actually become louder when we have only turned attention to it. On the other hand, it is certain that the two changes have much the same practical effects; both attention and intensity make the experience more important for consciousness. Attention also produces an increased clearness of outline. In this respect it has an effect similar to that due to increased closeness of the nerve terminations.

**The Distribution of Clearness.** — Much discussion has arisen in the last few years among the people who would make clearness the primary characteristic of the attentive consciousness, as to the way in which clearness is distributed over the field of consciousness. Titchener regards clearness as one of the fundamental attributes of sensation on the same level with quality or intensity. He first asserted that there are at any moment in consciousness but two degrees of clearness, — the centre upon which attention is fixed and the hazy background. This first statement was softened in large measure, however, by the admission that there might be differences in clearness in both upper and lower levels, separated by a marked break in

the degree of clearness between the two levels. Under the criticism of Wirth, who asserted that consciousness grades off gradually from the clearest point to the most obscure, Titchener renewed his investigation of the question, and found that there was a difference between individuals in this respect, that certain people belonged to the two-level type, others had a number of different levels or even approached the gradual passage from maximum to minimum clearness that Wundt had described as the universal type.

**Attention as Selection.** — The process of selection requires less description, although in its ramifications it probably takes more different forms and is a more important psychological fact than clearness. In part, selection results in an increase in the clearness of the content, — an element obscure at one moment becomes clear at the next; in part, the process selected rises from complete obscurity to a dominating place in consciousness, a possible content is made actual at one stroke. We are concerned with it primarily in its latter form when a stimulus that has been present but ineffective, suddenly rises to a prominent place. In later discussions it will be seen that the fact of selection is of fundamental importance. Not only stimuli but also ideas are selected. Control of association is selection and through ideas we reach decisions and govern actions. It will be found, too, that many of the same principles and the same conditions are involved in the selection of these higher or more complicated processes, that are involved in the simpler operations with which we are dealing here.

## Motor Aspects of Attention

**Motor Concomitants of Attention.** — If we turn from the function to the subordinate features of attention, we find that a characteristic quality is given the experience of at-

tending, both for the one attending and the observer, by accompanying movements. These are of varied sorts and degrees. Most important in practice are the actions involved in the accommodation of the sense organs. As one attends, the organ adjusts itself to give the best possible conditions for observation. The eye at once turns so that the object falls upon the fovea, the lens without further thought is given the right curvature, the eye is in consequence focussed for the distance of the object, and the two eyes are converged to permit both to see it with the fovea. Each of these adjustments is made without specific intention and usually without knowledge that they have been or are being made. One cannot contract the ciliary muscle to adjust the lens, by direct impulse. The only way to move the muscle is by attention to objects. If one attends to a distant object, the muscle relaxes; if one attends to a near object closely, it contracts, but this is the only way that it can be made to act. The same statement holds in less degree of turning and converging the eyes. The movement follows at once upon attention and is always a result of attending. In the other senses, the adjustments of the sense organs are less striking, although still present. The head is turned toward the source of sound to increase the certainty of receiving the tones. This is particularly noticeable if one ear be defective. The head will then be turned to one side when listening, to receive as much as possible of what is being said. The muscles in the middle ear probably have a protective function only, and play little part in attentive listening. When one is asked if one notices smoke, sniffing follows automatically to bring as much air as possible to and through the nostrils. Similarly, when a cook passes critical judgment upon a product of his art, the substance is pressed more closely against

the tongue by bringing the tongue against the roof of the mouth. In feeling a surface the hands are kept in motion, in order that the slighter irregularities may be noticed. In the blind this frequently develops into a series of slight movements of the finger tips made automatically and almost unconsciously. Comparing weights calls out similar lifting movements of the whole arm. Each sense, then, has a series of accommodatory movements that make the sensation more adequate and complete, movements that come without thought, are an immediate outcome of attending, of the desire to know more about the object in which one is interested.

**Mimetic Movements.** — Another characteristic group of movements is carried out by the voluntary muscles of all parts of the body, which depend for their character upon the nature of the thing attended to. Every movement that is absorbing attention or that is watched attentively tends to induce or be accompanied by similar movements on the part of the onlooker. Thus if one is watching an athletic contest closely, it is probable that one will make slight movements in imitation of the contestants. This tendency to act out ideas explains many of the cases of mind-reading and similar processes which approach the occult. Slight movements made without the knowledge or intention of the one and interpreted without the knowledge of the other serve as a basis for the communication. The capacity for interpreting these slight unconscious movements is found in animals as well as in man. The feats of "*Kluge Hans*" and the Elberfeld horses, which seemed to do sums and perform other wonders, were found on closer examination to depend in part upon noticing signals from the trainers which were given without the knowledge of the trainers. Thus a horse, when given a sum on the board,

would begin to stamp and continue the movements until the trainer indicated his satisfaction by some slight movement. These movements of the muscles of the face and of the bodily attitude constitute a large element in the appreciation of the mental attitude of a companion.

**Diffuse Motor Discharges.** — Still another large group of movements of the voluntary muscles accompanying attention is constituted by a contraction of most of the muscles of the body, due to a general discharge of impulses, a sort of overflow of motor excitations. As one attends strongly to any object one becomes tense, the brow wrinkles, the teeth are set, the fists may be clenched. The degree of tension increases with the degree of attention. One uses the feelings of strain subjectively as a measure of the amount of attention, and one also regards the amount of contraction as a measure of the attention of another. It is not necessarily true that the efficiency of attention is measured accurately by the amount of contraction or of the resultant feeling of strain. These strains seem to be more pronounced when the resistance to be overcome is great, rather than when one is attending to the best advantage. But it is taken by the individual himself as an indication of the effort that he is exerting in attention, or of the effort that he is exerting in any field. Closely connected with these general contractions and accompanying marked attention is the inhibition of all movements. Some individuals must stop any movement they may be engaged in when they begin to attend, and in all there is checking of movements when attention becomes close. It can be noticed most clearly in an audience. When inattentive, there is always a sound made by the rustle of garments, by other movements, each in itself too slight to make a noticeable noise, but which in the sum produce a marked disturbance. As

soon as the audience becomes attentive, all this stops and silence ensues. These inhibitions are of value in listening for faint sounds; and in many other sorts of attention they may increase the effectiveness of the sense in some degree. While necessary for audition, they have become an accompaniment of all attending.

Changes in non-voluntary physiological processes also are present. These are perhaps most strikingly seen in the checking of respiration. As one attends, the breathing is checked. In a short period of profound attention the breath will be held and a sigh or deep inspiration will follow relaxation. In longer periods the breathing first becomes quick and shallow; in still longer periods it is slower, but also more shallow than usual. Similarly, there are changes in the circulation. The heart beats more quickly, the blood vessels contract in the periphery and expand in the brain, the blood pressure rises, the pupils are dilated, tears are secreted which give the bright eye of interest. Each of these movements renders the organism more efficient. Holding the breath removes the noises of respiration that might interfere with faint sounds. The quicker heart beat and increased circulation in the brain prepare for appreciation of the conditions, and for the activity that may follow. Attention, then, is a physical as well as a mental process. Accompanying increased appreciation of some one sensation or stimulus is a widespread irradiation of impulses to the muscles. These serve to increase bodily capacity, are an indication to an onlooker of attending and of the direction of attention. The sensations of strain which come from the contractions are assumed to measure the degree of attention. Most so-called mental tension is physical, due to these muscular contractions.

## Limits of Attention

**The Range of Attention.** — One of the concrete problems that has been frequently discussed and most often measured in connection with attention is its range, the number of things that may be perceived at once. The experiments have been carried out by making very brief exposures of a number of objects, and asking an observer how many have been seen. The exposure is limited to a fifth of a second or less, a time which does not permit any change of the attention or movement of the eye. Results agree that four or five objects may be seen at a single exposure. It is interesting to note, too, that the number of objects that may be seen is relatively independent of the size or complexity of the object. One dot, a group of three or more that makes some regular figure, a letter, or a small word are all seen with approximately the same ease. In fact, a short word is more certain to be recognized than a single letter. What constitutes a single object is fundamentally that it has been used or treated as a single thing, rather than its physical complexity. The number of auditory impressions is slightly greater than the visual, but they must of course be given in succession. Eight single ticks of a metronome may be appreciated when heard without rhythm, and when combined in a rhythm as many as forty — five groups of eight each — can be heard in a single unit. The experiments also make it probable that the objects are not really seen all at once but that they are counted after the exposure in the immediate memory or memory after-image. Careful examination of the process of attending to objects exposed for an instant shows that the real study of the object is made after the exposure. Impressions persist in the memory after-image with considerable vividness for some two

seconds, long enough to count the five objects successively. One really attends, then, to but a single object at a time, but five successive acts of attention can be completed before the vivid memory image disappears.

Much the same problem has been raised with reference to how many processes may be carried on at once. Occasionally one reads that some man is able to do two or more things at a time. Cæsar was said to dictate to several secretaries at once, and similar tales are told of others. Experiments made to test the point all indicate that more than one process may be carried on at one time, but only provided some of them are sufficiently automatic to require no attention. Thus it is possible to write from dictation and add mentally at the same time, and the time required for doing both will be less than the sum of the times for doing each separately. If it is attempted to do three things simultaneously or to do two things even one of which has not become pretty thoroughly automatic, more time is required to accomplish them together than separately. Here again it seems that one can attend to but one thing at a time, although it is possible to start one series of activities and let it go on of itself while one attends to something else for a time. Attention changes from one to the other just often enough to keep the different processes going.

**The Duration of Attention.** — Another question of similar character is how long one may attend without a break. This question has been given different answers at different times, and the answer depends in part upon what is meant by the question. Speaking roughly, one may attend to the same general subject, may read a book, for example, for an indefinite period. Careful observation of the course of attention to faint stimuli, however, shows that they will

be appreciated only for short periods; they cease to be noticed in the intervals. Thus if one listen to the ticking of a watch or the faint tone of a telephone at a little distance, it will be observed that the sound will be heard for an instant and then will disappear, and these alternations will continue as long as one listens. Similar fluctuations are present during the observation of faint visual stimuli. The explanation of these fluctuations has been variously given as due to fatigue in the sense organs, either of the muscles or of the sensory endings, to fatigue of the sensory regions in the cortex, or to changes in the blood supply to the cortex, and even to fluctuations of mental energy. The explanation cannot be regarded as completely agreed upon, although considerable evidence has been given in favor of all but the last theory. What is probably more truly a fluctuation of attention is seen if one will keep a record of the time that one can fix upon some single, simple object, a dot or a single tone. It will be seen that the single object will dominate consciousness for only a second at the most, then something in the neighborhood will crowd out the first, or a memory of some event of the past will intrude to exclude it. Between each of the other events, attention will go back to the dot. The observer will be sure that the dot has been present all the time, but it will not have been attended to. It seems that one can attend strictly and definitely for a very short time, a second or so. In addition there are waves of increased effectiveness which come and go every six to ten seconds. These probably depend upon fluctuating physiological processes, central or peripheral. If by attending to the same thing is meant attending to a general subject that contains changing elements, it is possible to attend for several hours — the length of time depending upon the nature of the material, the strength of the observer, and

other conditions. If, however, we mean attention to one thing exclusively one can attend only a second or less.

**Attention and Distraction.** — It is very interesting to note that, on the whole, attempts to distract or to interfere with the attention of an individual usually result not in decreased, but in increased efficiency. Psychologically this was first noticed when attempts were made to measure attention by determining how much distraction was required to prevent the observer from performing some prescribed task. Almost without exception, experiments of this type show an increase rather than the expected diminution in efficiency during the distraction. A long investigation by Morgan has given an indication of the reason for this result. Morgan had his observers make complicated calculations while records were kept of the breathing and of the pressure which was made in writing answers. The individuals undergoing the test would work undisturbed for a time, and then a phonograph would be started or other disturbing impressions introduced. The course of the work showed that there was in most cases an increase in the amount of work done. This increase would continue as long as the distraction lasted and the rate and accuracy of work would then decline below that which preceded the distraction. The explanation was found in a study of the records of physiological processes. In writing, pressure upon the paper increased at the moment of distraction, the respiration became labored and showed that the observer was aiding his work by slight movements of the vocal organs. All showed clearly that there was increased motor tension. This was an indication of increased nervous action, which was sufficient to augment capacity to a point which more than overcame the effect of the distraction, although at the expense of greater fatigue. One can parallel these results

in daily work. Occasionally, and in some individuals generally, a disturbance will increase the capacity for work. The fact that the greater amount of work is at the expense of greater fatigue probably makes it undesirable to work in a disturbing noise unless necessary, but when necessary the increased accomplishment compensates for the discomfort.

## The Conditions of Attention

**Objective Conditions.** — The underlying causes or conditions of attention are to be found in the antecedents of the attending process in the individual himself and in the material that offers itself from the outside world. On the one hand, the individual attends because he is at the moment or in general of such a character that he must attend to the particular thing at the particular time; on the other hand, the characteristics of some stimulus and the general nature of the environment are such that he cannot avoid noticing it. If one asks why any individual notices any particular thing at any particular time, one will find the answer either in the nature of the environment or of the individual. The objective conditions may be found in the attributes of the stimuli that are arousing the sense organs. The intensity, size, and duration of a stimulus and its contrast with the surroundings determine whether or not it is likely to be attended to. Loud sounds, bright lights, strong odors, force themselves upon consciousness; while less intense stimuli fail to attract notice. Contrast plays a part, as may be seen from the fact that a fairly bright light in the dark attracts as much attention as a brilliant light in full day light, or a light footstep in the silence of the night as much as the automobile horn in the midst of a dense street traffic.

It is interesting to note in connection with objective

factors that change is an essential element in arousing attention. One quickly becomes adapted to a continuous stimulus and ceases to notice it. A constant light is unnoticed, but the shadow cast by the passing of a cloud at once intrudes upon consciousness. The slight noise of the burning gas drops into the background, and as Fechner pointed out, the miller is oblivious to the sound of his mill, but the slightest change induced by a defect will be observed at once. The cessation of the stimulus in this case is as effective as an increase in the sound. A clock that has been ticking unnoticed in the study will be noticed when it stops and the last few ticks will be heard, — sounds that would have had no effect upon consciousness had they not ceased. The decrease in the size of an object moving directly away from us attracts attention almost as certainly as does the increase in size due to its approach. Each of these effects of objective stimuli might be explained as due to the universal characteristics of man or to the inherited capacities of his nervous system. But since they are universal to all nervous systems it seems simpler to regard them as of objective origin, than to assert that man's physical organism is adjusted through heredity to respond to stimuli possessing much energy and particularly to changes in the amount of energy affecting a sense organ.

**Subjective Conditions.** — More truly characteristic of the attention processes are the subjective conditions. We ordinarily think of attention as a free act by which we turn to one thing which at the moment it pleases us to notice, and exclude all others. But frequently there is no conscious antecedent desire, and, where there is, the desires have their antecedents in the experience of the individual and these are to be regarded as the real conditions of his attending. Sometimes he knows that he desires to attend because of

the antecedent experiences; more often he first finds himself attending and never knows why. If we examine the nature of attention in the light of the history of the individual, we may distinguish five different groups of subjective conditions.

*I. Immediately Preceding Sensations.* — The first group of conditions refers to the immediately preceding sensation. This can be best illustrated by hearing out overtones. If one is listening for an overtone in a note played on the piano, and has heard another note of the same pitch just before, he will distinguish it easily, while unless he has considerable training, he cannot hear it without this aid. So if one desires to hear the first overtone of *c* on the piano, and will strike *c′* just before he strikes the *c*, he will notice the overtone, the *c′*, without difficulty. Again an object just seen in a particular place will strike the eye when one seeks for it, where previously it would not have been noticed. Very much the same statements may be made of the idea in mind. If one can call up a definite image of what is to be seen, the corresponding object will be noticed. It is probable that the skill of the practiced observer in hearing overtones is due to the fact that he can recall accurately the tone that he is to hear. This definite image replaces the sensation in its effect of making the overtone likely to come into mind. Similarly, in a puzzle picture, to recall the concealed face in its actual place is a guarantee that the image will be recognized when one looks a second time. The image definitely recalled serves to aid the entrance of the corresponding percept, in the same way as does the immediately preceding sensation.

*II. Purpose or Mental Attitude.* — Most important and striking of these subjective conditions is the influence of a factor that is variously designated the *intention*, the *purpose*,

or the *question* in mind at the moment. When one has the intention of seeing a particular thing, that thing will come to consciousness. If some one suggests that you look for a cell in the field of a microscope, the probability that you will see it is thereby increased. In daily life this purpose is the determining factor in all observation. One usually sees or hears what one desires to see or hear, or what harmonizes with the intention. All that does not harmonize with that purpose, unless especially favored by objective conditions or other more general subjective conditions, might as well not have been offered to the senses. If one is interested in what an individual is saying, one will not notice his accent no matter how unusual, and if one is a phonetician and intent on the study of the peculiarities of speech, the meaning may be altogether lost. One does not notice the wall paper in a room unless the pattern is striking, or one is deciding on wall paper for one's self and so has that as a dominant purpose at the time. Some objects that have been under one's eyes for years may never have been noticed unless some purpose made it desirable. To use a familiar instance, the reader cannot say without looking whether the four on his watch is iv, 4, or iiii, in spite of the number of times it has been looked at. One looks to learn the time, not to see how the numerals are printed, and sees just what one looks for, and nothing else. This is typical of most observation. Man is blind to what does not correspond to his momentary purpose.

This purpose or mental attitude may be aroused, either from without or from within. From without it may be due to a question asked by another, or to some task that has been set, or problem that has been raised by one in authority. From within, the purpose usually arises by a suggestion from something that has been seen. Something

external or internal starts a train of associations. That raises a question about an object present, and one looks to the object for an answer. The answer to the first question suggests another problem, and thus a train of associations in the series of questions leads to one observation after another. Observation is most frequently the result of a series of problems self-set for solution. When one has the problem or the question, finding the answer is relatively easy. Without the problem, observation is indiscriminate and relatively unprofitable. In this sense thought usually precedes observation, but the thought itself grows out of preceding observation, and so both are to be regarded as parts of a continuous progression in which each thought suggests attention, and the results of each attention, a new thought, in a succession broken finally by the irruption of an intense stimulus or the necessities of the daily life, and this in turn starts a new series of questions.

*III. Education and Attention.* — A number of more remote conditions also aid in preparing an individual to attend in a given way at any moment. First of these is the earlier training and previous experience. This works in two ways: in the first place, it increases capacity for observation of the object one desires to know about, and it largely determines what one desires to see. The skill of experts in any sort of observation depends upon training. The skill of expert microscopists in any realm, of musical critics, of tea and wine tasters, and of the woodsman in tracking game and in seeing the signs of the forest, all comes from training. The expertness depends in part upon knowing what to look for, of having in mind the problems that are to be solved in a particular connection; in part, the skill in discrimination grows with practice, and is probably dependent upon a number of physiological factors. Train-

ing has also obvious effects in determining what sort of stimuli shall be selected for attention. This works in two ways. In the first place, it helps to raise questions, to organize purposes. One cannot have a purpose without some preliminary knowledge of the thing to be seen. What to look for in animal structures is known in any considerable degree only by individuals with some training in zoölogy. The trained machinist has a series of questions in mind as he begins to examine the engine that you have called him to repair, and with these problems which have grown out of his experience he looks with a definite series of purposes and easily discovers the source of trouble. But, secondly, even with no definitely conscious purpose, one sees the things that one has been accustomed to deal with, or that one has been trained to see. The printer without effort sees details of a book that escape the ordinary reader.

*IV. Social Forces in Attention.* — Still another important group of influences are the outgrowth of social instincts. These compel respect for the ideals that one takes from society, and make one strive to do and observe certain things because of the fact that others expect such behavior. The student attends to a lesson when fatigued or when the lesson is not interesting in itself because he desires to make a good record, to pass an examination. Or again, a man desires to make a good record for the sake of the approval it will win from persons he respects. Or selecting a more permanent aspect, one desires to obtain a satisfactory knowledge of a subject for the value it may have in later years, or in the profession that has been adopted. Again, however, choice of a profession depends largely upon the social favor that the profession has in the group with which one is acquainted. Even the belief that the particular subject will help in the profession is often taken from

society. It is a preference for the remote as opposed to the immediate good, but the more remote is accepted as good and obtains impelling force because of the influence of society. Society approves each separate step, as well as the attainment of the end; its pressure is felt throughout the whole course of the attainment, and thus at once guides and compels towards that end. For our present purpose it may be regarded as the source of all attention from constraint, of all attention against one's momentary desire.

*V. Heredity and Attention.* — A final condition of attention, most remote in time, is found in the hereditary disposition. This heredity may be either immediate, as in the inheritance of individual traits, or distant, as in attention due to general instinct. The former is less easy to illustrate or to demonstrate, but it seems probable from special studies in attention and the more general studies in heredity, mentioned in Chapter V, that certain of the tastes of an individual, which are either derived from the natural direction of his attention or control it in certain respects, are inherited from his parents. The more general heredity is seen in the fact that one attends to moving objects, to personal combats, to all objects that are likely to be especially beneficial or injurious. In general, if one asks why one attends to anything at a particular time, the answer may be found in the nature of the external objects, or in the different mental states at the moment, in the experience of the immediate or of the remote past, and finally in the inheritance of the individual. As has been pointed out, these coöperate in many ways and vary independently from moment to moment, but could we know the individual completely in all of his characteristics, his past history, and the influences working upon him from the environment, it

would be possible to say fairly closely, even with our present knowledge, to what he would be likely to attend.

### Attention and Association

**Control of Association.** — Selection is quite as important in controlling the course of the associations or in determining the ideas that shall be recalled or suggested, as in choosing the sensations that enter consciousness. It is evident that the mere strength of connection between ideas would give only a rigid, mechanically determined series of thoughts with no flexibility or adaptation to varying conditions such as is required in logical thinking or purposeful imagination. This inadequacy of the associative connections to explain the real course of thinking has led many to abandon the theory altogether, in spite of the fact that in some degree the importance of old relations in determining what shall be recalled has been recognized all through the history of psychology. It seems more in harmony with the facts to accept the view that fundamentally all recall goes back to association, that each impression recalled must be suggested by the preceding, but that since each idea has been connected with many others, there must be other conditions which have united to bring back just that idea and no other; or, viewing the process in advance of the recall, the arousal of one idea, connected with the thought in mind, rather than another depends upon a number of forces, which work together with the associative tendency in determining the recall.

**The Goal Idea.** — Two different theories, at present current, attempt to remedy this deficiency in the doctrine of association. One proposed by Aschaffenburg and much used by the psychiatrists would refer the determination of the course of ideas to the effect of the final idea in the

series, — the goal idea. Thus if the goal of the sentence is to describe the weather, one set of words will be suggested; if the aim is to decline an invitation, another series of words may be called out, even if one start with the same word. When the course of thought leads to the goal, it is said that the goal idea dominates it; if it wanders at random by virtue of the strength of the connections between each pair of ideas, we have to do with another sort of thought. For the diagnosis of mental disease, thinking dominated by goal ideas is normal, while, when the goal idea is lacking or is of slight effect, one has an indication of mental abnormality. There can be no doubt that these terms describe an important difference between types of thought, that associations may be classified in this way. It is open to objection in that it gives merely a descriptive classification rather than an indication of the effective causes or conditions in the course of ideas. One cannot think of the last idea in the series as exerting an influence upon those that precede it. A force cannot be regarded as exerting an influence before it comes into being.

**Mechanical Factors in the Control of Association.** — On the other theory the same facts are taken into consideration, but the explanation is in terms of determinants rather than of goals, of antecedent rather than of consequent events. We may take over almost bodily our conditions of attention and apply them to enumerate the factors that determine the selection of one possible associate from the others. Corresponding to the objective conditions, we find the factors that determine the strength of the connection between one element and those that have been associated with it. These have been shown to be the *frequency* with which the two elements have appeared together, the *recency* of their association, the degree in which they were

attended to or the *intensity* of the stimuli that called out a response at the time of their earlier appearance, and the *primacy* of the association. Professor Calkins has shown that the earlier one element enters into an association with another, the more likely it is to be recalled with that than with any other with which it has been associated at a later period. It should be added that Galton found that very many of the ideas in a train came from youth. He kept a list of ideas that were suggested to him by objects or words, and then traced them to the time of their original experience. Thirty-nine per cent were found to come from boyhood and youth, 46 per cent from the period of subsequent manhood, and 15 per cent from quite recent events. This indicates that impressions received in youth are better retained and are stronger in their connections than those received at later times. This may be said to be due, either to primacy, that is the greater degree of retentiveness of the associations first formed, or to the greater interest in the events of the early period of life. Professor Calkins also found that primacy was an important factor in the determination of the strength of associates, even when they were formed in adult life.

**Intensity and Recall.** — A number of experiments from Ebbinghaus prove that both the frequency and recency of associations are important elements in the determination of the probability of recall. Intensity does not lend itself so well to experimentation, but chance observation indicates that the more intense stimulations leave more permanent effects. Under this head come cases in which the intensity is of subjective origin, is due to a strong feeling or to close attention. It has been shown that the degree of attention increases the likelihood of recall, and, while the experimental case for feeling is not so complete, there

is good evidence from everyday life that this, too, serves to increase the closeness of the connection. As a result of these objective conditions, the tendency of any idea or partially aroused neurone to arouse some other is constant. Furthermore, were this strength of connection the only thing to be taken into consideration, it would be very difficult for the connections to be changed. The idea recalled by any given idea would be determined once and for all. The only way one association could be broken and another substituted would be to permit a long lapse of time and the formation of some very strong new association. It would mean, in any mind subject to its rule, a perfect mechanism with no possibility of breaking away from its domination.

**Subjective Conditions of Recall.** — This tyranny of association is tempered by the subjective conditions of attention which play a part here, as well as in the entrance of sensations to consciousness. By far the most important of these is to be found in the mental attitude of the moment, the purpose or problem that is set the individual. If one be given such a word as *dog*, a very large number of associates can readily be recalled. If, however, it is coupled with the request to name the class to which it belongs, vertebrate, animal, or some other more general term will be aroused. While if one is asked to give a member of the class, a species of dog or the name of some particular dog is spoken. There is still room for selection within the group, but the group itself is very much narrowed. Similarly, if two numbers are shown written one above the other and a line drawn beneath, as $\begin{array}{r}12\\6\\\hline\end{array}$, six, eighteen, or seventy-two might be associated with them. If they ap-

pear in a check book or in other real relations, the purpose and the knowledge of what has gone before serve to determine whether one or another number shall suggest itself. If the problem is set by another, if the sum appears in a series in which one has been asked to add, subtract, or multiply, that request will suffice to suggest the corresponding figure. In any case, either the task that has been set by another, the demands of the situation, or the attitude that one may happen to be in, will choose from among the possible associates the one most suitable. In addition to the setting, education and the social influences that are behind voluntary control of attention also have an important part in the guidance of ideas. While association provides the possible paths along which ideas may flow, these possibilities are made actualities by the more subjective conditions derived from the earlier experience and present intentions of the individual, and the necessities that bear upon him at the moment. All the factors that control attention serve also to select the associates.

## Forms of Attention

**Three Forms of Attention.** — It is customary to divide attention, whether applied to external objects or to the control of ideas, into three groups, — voluntary, involuntary, and non-voluntary. In popular terms the basis of division is with reference to the presence or absence of the will. As we do not care to raise the question of the will at the present time, we can make the classification with reference to the conditions and characteristics of the attention process discussed above.

*Involuntary Attention.* — In general, it can be seen that the attention called involuntary corresponds to attention that is determined altogether by the objective factors. We

attend in spite of ourselves because the stimulus is strong enough to force itself into consciousness, whatever the state of consciousness itself may be at the moment. Attending is against the will, against the desire of the individual at the moment. We desire to read, and the noises of the street force themselves upon us, or we desire to recall the book in which a certain statement was made, and a large number of ideas keep forcing themselves upon us. In the latter case the associations of irrelevant things are so strong that the relevant idea is kept out.

*Voluntary Attention and Effort.* — Voluntary attention, on the other hand, is that which is determined by social pressure. The desire to attend is not one that springs spontaneously, but is due to the impulsion of some remote end. In most cases, a struggle between the immediate and the remote good or pleasure is involved. Usually, too, as has been said, the remote good is impressed upon us by some form of social pressure. The approval of some part of the immediate social group is necessary to make the distant goal more attractive than the inherently pleasant processes that would lead us away from it. In this sense social pressure is the real motive force behind attention, the force that holds the individual to the less pleasant in the face of the more pleasant. The characteristic conscious accompaniment of voluntary attention is a mass of strain sensations, sensations which, taken together, constitute the feeling of effort. As was said in the discussion of the motor accompaniments of attention, all attention involving conflict of motives tends to arouse diffuse contractions in a number of muscles, contractions which are in themselves of no great effect upon the attention process, but which are accepted as an indication that some force is active. They make us feel active, are said to constitute a sign of

the activity of the will. So far as we now know, they are not a cause but an effect, they are a sign, not of a new force, but of a conflict of conditions. That they have no good effect is evident from the fact that they do not accompany the most effective attention and, when they appear, usually die away as soon as the highest stage of efficiency of attention is attained. Voluntary attention is due to social pressure and is accompanied by strain sensations. All strain sensations taken together constitute what we call the feeling of effort.

*Non-voluntary Attention and Interest.* — The non-voluntary form of attention includes all classes not previously covered. The more important conditions are the mental attitude of the moment, the momentary purpose, education, and heredity or instinct. These seem to induce attention in accordance with the momentary nature of the individual; they constitute in sum total the conditions of desire. The characteristic accompaniment of this form of attention is interest, a feeling of pleasure due to the lack of conflict. In so far as it is strictly interest, it is a pleasure derived from the mere act of attending, rather than from the nature of the thing attended to. Why it should come or how it originates need not concern us here; in fact, no satisfactory explanation has been given for it. It is essential to emphasize that both interest and the feeling of effort are accompaniments or effects, not causes. After all, then, these three divisions of attention are not entirely distinct. All forms produce the same effects in consciousness; they are distinct only in that in certain cases the sensations of effort or the feeling of interest accompany them; they gradually shade over into each other without sharp line of division. Attention is a unitary process.

## The Physiological Basis of Attention

**The Physiological Explanation of Attention.** — On its physiological or nervous side, attention may best be pictured as a preparation of one tract or set of tracts for action. The nature of this preparation in advance of the entrance of an idea varies for the different subjective conditions. The immediately preceding stimulus and the idea in mind can be pictured as due to the effect of a previous stimulation of the same tracts, which in consequence are still partially active at the moment the new excitation is received. This corresponds to the fact noted in the preceding chapter that the nervous response continues for several seconds in relatively high degree and probably for a considerably longer time in some degree. The entering stimulus, finding these tracts already active, produces a greater excitation than it otherwise would or, if several stimuli of approximately equal intensity are presenting themselves, that one produces its effect for which the way has been prepared by this partial excitation.

**Attention as Facilitation and Inhibition.** — The influence of attitude or purpose is the result of the spreading to a large number of associated paths of the impulse developed by the stimulus which arouses the attitude. One may think of the interaction of different parts of the cortex during attention as the effect of a widened association. As was said in the fifth chapter the excitation of a neurone not merely arouses those neurones which specifically excite movements or are accompanied by overt consciousness, but it also exerts a tendency to arouse certain neurones and to suppress the activity of others. When one is asked a question, the question, by association, tends to arouse the possible answers. This means that the impulse

spreads from the auditory neurones that receive the question to the others associated with it in previous experience. In addition, it would increase the tendency to activity in a number of other neurones related to the first, and would probably check the activity of others which were not connected with the first. This would make it very likely that any stimulus that affects any of the prepared neurones would be appreciated, while all other stimuli would be less likely to be noticed than they would be if there had been no preliminary preparation. An attitude has a similar effect. When in a biological laboratory, the parts of the cortex that have received stimulation in connection with the observation of animals are partially active or are at least prepared for activity, while other neurones are rendered less likely to respond.

The effect of education is to prepare these systems of paths so that they may be excited by the particular stimuli or the particular occasions. It is essentially a process of organizing cerebral cells into groups so that one entire group, as well as some particular associate, may be aroused or partially aroused by a suitable stimulus. Each of these processes may be regarded as an explanation of the selection, either from among the stimuli which seek to enter consciousness, or between ideas that are associated with the particular idea that serves as excitant. Thus on the nervous side, the course of impulses is determined by the action of very large numbers of neurones, many of them very remote from the neurones which are actually the seat of the processes attended to. The cortex acts as a unit rather than in parts, just as, on the side of consciousness, practically all experience unites in determining the course of any single element of consciousness.

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# CHAPTER X

# PERCEPTION

## General Remarks

Perception may be defined as the process of becoming aware of an object. A perception is different from sensation in that it is the appreciation of an object as an object, while a sensation is not known for itself or at least by itself, but is always a part of something else from which it is abstracted. The perception always is initiated by some sensation. It begins with the stimulation of some one of the senses. But as a result of that stimulation we add to the sensation a mental construction or series of mental processes which result in giving us the impression of a whole object.

**Perception a Process of Association.** — The additions are of at least three kinds. In the first place, one sensation may fuse with others from the same or different senses. This is our experience when we see an object and touch it at the same time. The two impressions combine to form a single or common process.

More frequent and more important is the second instance — the addition of memory images. When an object has been seen and touched at the same time on various occasions, we have the formation of association processes which makes us recall the image of the object when it is touched and also recall the sensations of touch, that we had received earlier, when the object is seen. Supplementing by memories or centrally aroused impressions is most frequent and most prominent among the elements in perceptions. We are

constantly being led on from the sense impressions themselves to recalled or added memories. Our perceptions are mosaics of sensations and memories in which we do not distinguish one from the other. In filling the blind spot, for example, we add, to the sensations received from the retina surrounding the blind spot, imagined processes suggested by them, and do not notice where the actual sensations cease and remembered impressions begin. In all other senses we make similar additions which fuse with the sensations into a uniform whole which cannot be analyzed into parts. A perception is a fusion of sensation and memories in which sensation and memory are indistinguishable.

**Perception Involves Wide Correction of Experiences.** — In the third place we find that the object recalled is usually corrected in ways that go beyond the mere addition of memories. The object which we perceive is always regarded as existing in the outside world, and that object is seen as we believe it must exist in the outside world. In many cases the object, as we think it, is not as we could have seen it at any time in the past. The corrections could not be made by referring from the present group of sensations to a group that might have been received at any single earlier time. In addition we change the interpretation in an indefinite way to correspond to a number of different experiences of the object. We tend to see an object as we know it must be on the basis of all the experiences that we have had of it, rather than by correcting a single impression of the present in terms of a single experience of the past. In the interpretation we replace the group of experiences actually presented by another group that seems to us to be more in harmony with everything that we know. The simplest illustration that can be given is the way in which we see the top of a table or other rectangular surface. It

is on the retina a figure with the front and back sides approximately parallel but with the other two sides slanting towards each other and usually making obtuse and acute angles with the front. This figure is almost always finally interpreted as a rectangle. We could never see the figure in such a way as to give this impression. The nearest approach to it is if we should have one eye directly over it. Even then the sides would not be straight lines but would be bent because they are received upon the curved surface of the retina. This figure with which we replace the rectangle is something that we know from all of our experience must be the object as it exists in the outside world, but it is not known to exist in that form because it has never been seen in just that shape; however, when we test it by building it or by fitting it into corners that we know are square, it proves to be rectangular. In other words we accept as real the construction that has proved on earlier test to harmonize with all of our experiences of that object. We see and hear by replacing or correcting our sensations as our experience proves that we must correct them if they are to explain the world as we have known it. It is little more than fair to say that we see these corrected concepts rather than actual sensations, or than mere combinations of sensations and memories, although both sensations and memories are the all important components of the perceptions. Instances in which we see these corrected and harmonized results of past experiences will be found to be numerous in our discussion of perception.

**Perception Implies Movement.** — These corrections in the light of wider experiences always involve a considerable amount of reference to action. The tests that we apply to the objects are frequently of a type to involve action. We know what objects are like because we try to manipu-

late them in various ways. One may go farther and argue that, since to every sensation there is some form of motor response, perception, too, must involve some motor activities, and that these motor responses are an essential part of our interpretation of the object. The behaviorists would go so far as to add that all that there is of importance in the percept is this reaction or group of reactions. Since their theory leaves little room for knowledge, it makes relatively slight difference to them whether we perceive through our movements or not. One must insist that response to movements modifies our knowledge and that the nature of the responses is an element that cannot be neglected in a discussion of perception, although it is not always possible, in fact has seldom been possible, to detect the elements that movement adds to the perception in individual cases.

**Percepts are always Things.** — A fourth fact that must be kept in mind is that we always think of the product of the process that gives rise to perception as something in the outside world rather than as a mere combination of mental processes. This hardly needs to be added from the standpoint of common sense because everything that is thought of at all is thought of as having real existence, as being part of the real external world. Still it is an important fact that as we receive a sensation from the retina we never think of referring it to the retina alone, but always regard it as an object. So direct and complete is this reference that we do not first receive the impression with the notion that it might be a mere image on the retina and then decide to refer it to a certain distance in the outside space. The reference is immediate. The correct construction is seen at once as an object at a certain distance, without any intervening activity of thought. The mental process is made to

mean an object in the outside world, and we are aware of the meaning alone. We know nothing of the group of sensations and images which must be the mental occasion for the development of the meaning. The matter might be put more definitely by saying that certain sensations have come to stand for an object in the outside world; and that we now accept the sensations that come in, as a sign that the object is present in the world without. But in all this, it should be emphasized that what we are immediately aware of is always the object that is meant and for which we have the sign, rather than the sensations or the signs themselves. These various steps and aspects of the development of perceptions we shall have occasion to indicate at each step in the examination of the concrete perception process.

In discussing perception we find it convenient to consider certain of the general aspects of objects first and then proceed to the more concrete phases later. All experiences have duration, and we in practice abstract these temporal phases from the particular happenings, and consider them apart from the events. We may conveniently discuss the perception of time with no reference to the filling of time. Space also is involved in the perception of all objects and can be discussed without reference to the particular objects in space. Other general aspects of experience are motion and rhythm. Each of these can be treated apart from its particular content and this simplifies the treatment of the perception of particular objects. We may begin with the discussion of space.

## Perception of Space

**Problems Concerning Space.** — Space is appreciated by means of at least four senses, — touch, vision, audition,

and the kinæsthetic sense. Of these, vision gives the most accurate and complete appreciation, touch combined with the kinæsthetic impressions stands next in definiteness, and the auditory space comes last. In actual practice all objects that are recognized as objects are thought of as existing in space, whether they are actually sensed or merely recalled. In the senses not mentioned, the spatial aspects are ascribed to one of the more definitely spatial senses; thus tastes are referred to the tactual impressions also received from the tongue, — or are somewhat indefinitely referred to space in general. Odors are usually ascribed to objects, but the localization is always uncertain and the quality may be thought of as independent of the organ, as general or all pervasive. Not only are the subordinate sensations referred to sight, but there is much cross reference between the higher senses. Different senses predominate in different individuals, but in all space interpretations several senses are involved.

Three different complexities of the space problem present themselves, although for sight and kinæsthetic impressions alone are all these problems to be considered. These three are the appreciation of *position*, of *extent* in two dimensions, and of *distance* or depth, the third dimension. The skin appreciates position and extent alone; the ear, distance and direction alone. We can start with the simplest problem in each sense and transfer what may be gained from that to the more complicated constructions.

**Perception of Tactual Space.** — Theoretically simplest of the space problems is the appreciation of the position of a point upon the skin. Experiments have frequently been made to determine how accurately a spot upon the skin may be localized. If one attempt to touch a spot on the skin, one will make an error that averages a centimetre or

so on the wrist or on the back of the hand, is smaller on the fingers, and considerably larger on the portions of the body ordinarily covered. This simple experiment indicates two facts: first, that there must be some way of knowing where the point touched is and that this guides the movement; and secondly, that this localization is not absolute, that it is subject to error, and more or less variable. One of the first theoretical attempts to determine what it is that gives a knowledge of position was made by Lotze. Lotze pictured the self as somewhere in the brain and as receiving impressions over the nerves from the surface of the body. Such a self might be thought of as constantly questioning what part of the skin gives rise to the sensations it received and seeking for signs that indicate their origin. Lotze asserted that the sensations received from different parts of the skin had different qualities. These different qualities were not described very definitely, but apparently were due in part to the character of the skin and the amount of tissue that lay between it and the bone. The quality of any spot on the skin he called its 'local sign.' If you will try to discover this local sign in the sensations from your own skin, you will find it very difficult. Careful examination of the sensations fails to disclose any such quality in addition to the ordinary skin sensations, — one knows immediately where the touch is but does not know how he knows.

Indirect methods of analyzing the local signs or means of localization indicate that it is dependent in part upon the nerve stimulated. When a member has been amputated, the sensations from the stump are still referred to the missing part, and when a portion of the skin has been displaced by a surgical operation without severing the nerves that supply it, sensations from the skin will for a time be given

the old position. It is true, too, that the accuracy of localization is greatest where the nerve endings are most numerous. These factors might be explained on Lotze's assumption that each nerve had a 'local sign.' They also have been interpreted to mean that localization is due to the movements called out reflexly. If each point on the skin were connected with a set of motor neurones that would cause the hand to move to the point touched or that would call out a slight movement toward the point, the movement might be used as a sign of the position. This motor theory receives some support from the fact that animals whose brains have been removed, and men in their sleep, will touch the point stimulated with a fair degree of accuracy. That it alone is not sufficient is probable from the fact that the normal animal makes the movement with greater accuracy. Still a third theory would make the localization due to the association of other sensations with cutaneous excitation. Often a picture of the point touched comes immediately upon contact. However, no one of these theories may be regarded as sufficient in itself. Rather must we assume that all have acted together to give a notion of each different position on the skin. As different points have been touched, the kinæsthetic have been associated with the visual sensations, and these with the sensations of contact and with any other impressions that may be concerned. After the notion has been developed it is called up by any contact.

**The 'Limen of Two-ness.'** — Much the same problem meets us in connection with the appreciation of a minimal extent. This has been studied by determining the least distance at which two points might be appreciated as two. Weber, who made the first experiments, found that this distance varied from approximately 1 mm. on the finger

tips and tip of the tongue to 40–60 mm. on the middle of the back. In general it was larger on the portions of the body ordinarily covered and, on the limbs, decreased regularly from the centre of rotation downward. Volkmann noted that it varies approximately with the amount of motion of the member and of the parts of the member in question. Goldscheider repeated the experiments by putting the points of a compass upon pressure spots, and found that two points might be distinguished when the points were on contiguous spots. His values varied from 0.3–0.6 mm. on tongue and finger tip to 4–6 mm. on the back. Later experiments by von Frey indicated that these values were too small unless the stimuli were applied successively. In these experiments, as in comparisons in general, successive stimuli are judged more accurately than simultaneous stimuli. It is also to be noted that practice and suggestion have marked effects. Values may be reduced one-half or more in a few weeks' practice. It is seen, too, that practice on one part of the body will have an effect upon the symmetrical areas that have not themselves been exercised.

The explanation of these values may be reduced in part to a matter of comparing 'local signs.' When two signs of position are much alike, they are confused and made to constitute one point. By sign of position may be meant, either the actual sensory qualities received from the points, if they exist, or the movements that must be made to touch each, or the suggested motion from one to the other, or reference to visual distances. Improvement with practice is suggestive of this process of analysis, as is also the greater acuity on the more mobile and in consequence more frequently used members. Larger extents probably depend more upon movement from one point to the other,

either of the member itself or of another exploring organ. A curious illusion that arises in the comparison of filled with empty space would indicate that the nature of the stimulation plays a part. If one is asked to compare a single empty space with a space containing other stimulated points, the empty space seems greater than the interrupted space. The explanation is difficult in terms either of movement or analysis. The importance of reference to vision should also be emphasized. Many individuals translate cutaneous sensations into vision, and do not appreciate the distance until this translation is complete. This statement may be verified if one will have another trace outlines on the skin, or press objects of different shapes against it. The blind must of course have an immediate appreciation in terms of pure cutaneous impressions or of movements. How these different factors coöperate is not as yet known, but it is undoubtedly a process that is much more complicated than the simple theories we have indicated would seem to imply.

**Retinal Local Sign.** — If one is to explain something of the spatial perception on the skin by reference to the influence of vision, it is also necessary to understand how position and extent may be perceived on the retina. The same problems meet us here and many of the same facts are present to provide the data for discussion. There is a lower limit of distance that must separate two points if they are to be perceived as two. On the fovea if two dots or lines are nearer together than .004–.006 mm., or an angular distance of 60″–90″, they fuse into a single line or dot. This may be regarded as the 'limen of two-ness' for sight. The effects of the inability to distinguish lines and points closer together than this minimum can be seen in the ability to distinguish letters in reading. The normal

eye can read letters when the width of the separate lines and the distances that separate them are each 1′. The Snellen types in the adjoining figure can be read at a distance such that the lines are separated by this amount or by .004 mm. on the retina. Stratton found that if two vertical lines placed one above the other were brought together at their extremities, a break in the line could be noted when they were displaced 7″ only. In this case, however, the difference in direction of the lines probably also gives a cue; it is not merely appreciation of the distance between points. As the distance that separates the centres of cones in the fovea is only about 40″–60″, it would seem that stimuli no farther apart than the centres of neighboring cones can be discriminated. As one proceeds outward from the fovea, the acuity diminishes very rapidly. Five degrees from the centre it has been reduced to one-fourth and at forty degrees to one two-hundredth of the maximum value. In twilight vision, where the cones are not involved, acuity is approximately the same in all portions of the field beyond ten degrees from the centre. It is zero in the fovea itself, and rises very rapidly to attain a constant value five to ten degrees distant.

Fig. 71. — Snellen types.

The theories of the appreciation of position and extent upon the retina involve the same principles as those advanced for the skin. The awareness of position seems to depend in some way upon the nerve element stimulated, as is evidenced by the fact that when a retinal element is displaced it still gives the old sign of position. Thus Wundt at one time suffered from choroiditis under one small portion of the retina. This caused a swelling of the retina and finally resulted in a small scotoma or blind spot. While the elements

of the retina were displaced in this region, the straight lines seen on it were distorted, and it was only after the rods and cones had been used in their new positions for a considerable time that the spatial relations became normal again.

**Theories of Localization** — This sign of position that attaches to the retinal element has been ascribed to the conjectural 'local sign' and to movement. Differences in the qualities of sensations received on different areas of the retina have been suggested as furnishing the means of distinguishing position. Even the difference in the quality of a color has been suggested as a sign. In the movement theory it is assumed that the tendency of the eye to turn in such a way that the point attended to shall fall upon the fovea constitutes the mark of position. The more general and inclusive the final explanation, the greater the likelihood that it will be correct. It is probable that the idea of position here, too, is a notion that has been gradually developed through experience of all possible sorts, that it includes reference to motion, to areas as known on the skin, and particularly to the movement of the fingers over surfaces as eye and finger explore them together, and a large number of more general practical tests. After the complex idea has developed, some peculiarity in the retinal element stimulated or the activities aroused by the stimulation suggest this idea or concept. Either such a highly complex concept of position whose origin has been lost in the course of its development, and which is now appreciated only for its meaning, must be assumed to constitute our idea of position, or we must leave the problem unsolved.

The perception of greater visual extents depends very largely upon the eye movements. This phase of perception has been investigated with more care for the eye than for the skin. Studies in the comparison of two lines show that

the appreciation of distance follows Weber's law, — one can appreciate an addition in length of from $\frac{1}{40}$ to $\frac{1}{60}$ to a horizontal line, an average of about $\frac{1}{50}$. Appreciation of difference in the length of vertical lines is slightly less accurate, an average of about $\frac{1}{40}$. This slighter degree of accuracy in perception of vertical movements has been connected with the fact that the vertical movements require two pairs of muscles and so a greater amount of effort than horizontal movements. They are thus less accu-

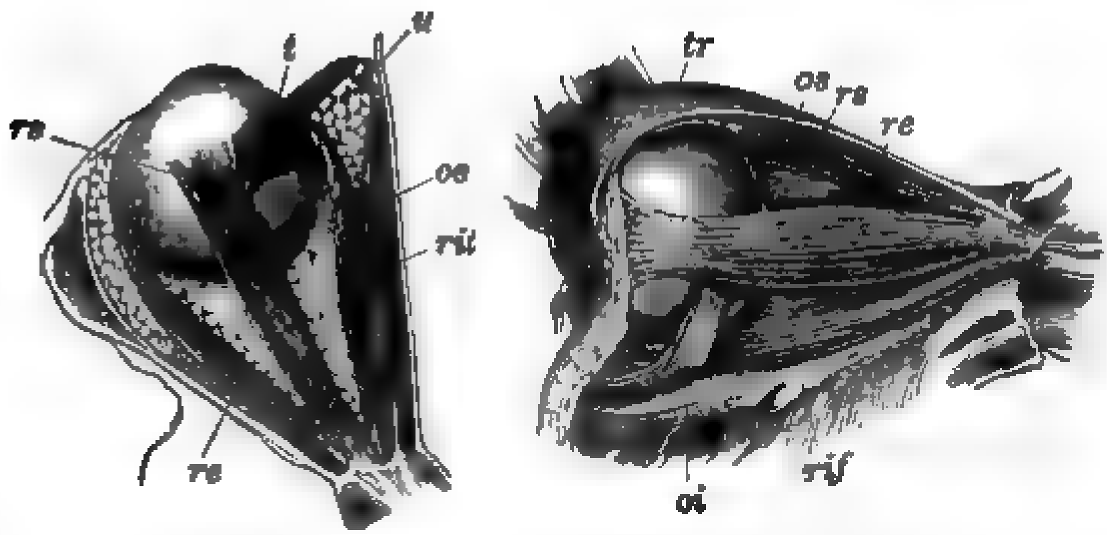



FIG. 72. — Muscles of the eye. *rs*, superior rectus, *rif*, rectus inferior; *re*, external rectus; *ril*, rectus internus; *os*, superior oblique; *oi*, inferior oblique; *t*, tendon of superior oblique which runs through the membranous pulley, *u*, on nasal wall of the socket.

rate and more difficult to compare. As one estimates the length of a line, the eyes move from one end to the other and the comparison is probably very largely through these movements. The qualitative characteristics or group of 'local signs' may also be involved; but here, as in the liminal values, they have not been clearly discriminated.

**The Eye Muscles.** — The importance of eye movement in the perception of space makes it desirable to give a brief statement of the muscular mechanism. The eye is moved by six muscles arranged in pairs, and named, from func-

tions and attachments, the internal and external recti, the inferior and superior recti, and the inferior and superior oblique. The recti muscles all spring from near the apex of the eye socket and pass directly forward to their point of attachment on the surface of the eyeball. The superior oblique also originates at the apex but runs forward to a ring of cartilage on the upper nasal rim of the socket and then turns backward to be attached behind the centre of the upper surface of the eyeball. The inferior oblique springs from the lower nasal rim of the socket and passes back to a point behind the middle of the lower surface. From the fact that the oblique muscles exert their pull toward the front, they turn the eyes in the direction opposed to their names. The direction in which the muscles turn the eyeball may be best indicated by the diagram taken from Hering. It will be seen that the internal and external recti muscles turn the eye in an approximately straight line; all the others turn it along a curve and if the eye is to be moved directly up or directly down, two muscles must coöperate (Fig. 73).

**Eye-movements.** — The eyeball turns about a point about 1.3 mm. behind the centre of the eye. The centre of rotation is 13.5 mm. back of the cornea. It should not be assumed that this point is absolutely fixed, — owing to the loose way in which the eyeball is held in its socket, it is slightly displaced as it turns, and the centre of rotation moves with it. Also as the eyeball turns, it is rotated more or less about its optic axis. This is called torsion. The amount of torsion increases with the amount of the movement, but is always present even for slight movements. Both eyes always move together. A single impulse is sent simultaneously to the same muscles of both eyes. It is as if they were a team of horses turned by a

single pull on a pair of reins. These movements follow the direction of attention, as was said in an earlier chapter. The only conscious antecedent is that some object in the field of vision shall catch the attention, then the eye muscles immediately contract in a way to bring both eyes to fixate the object. As points of reference for eye move-

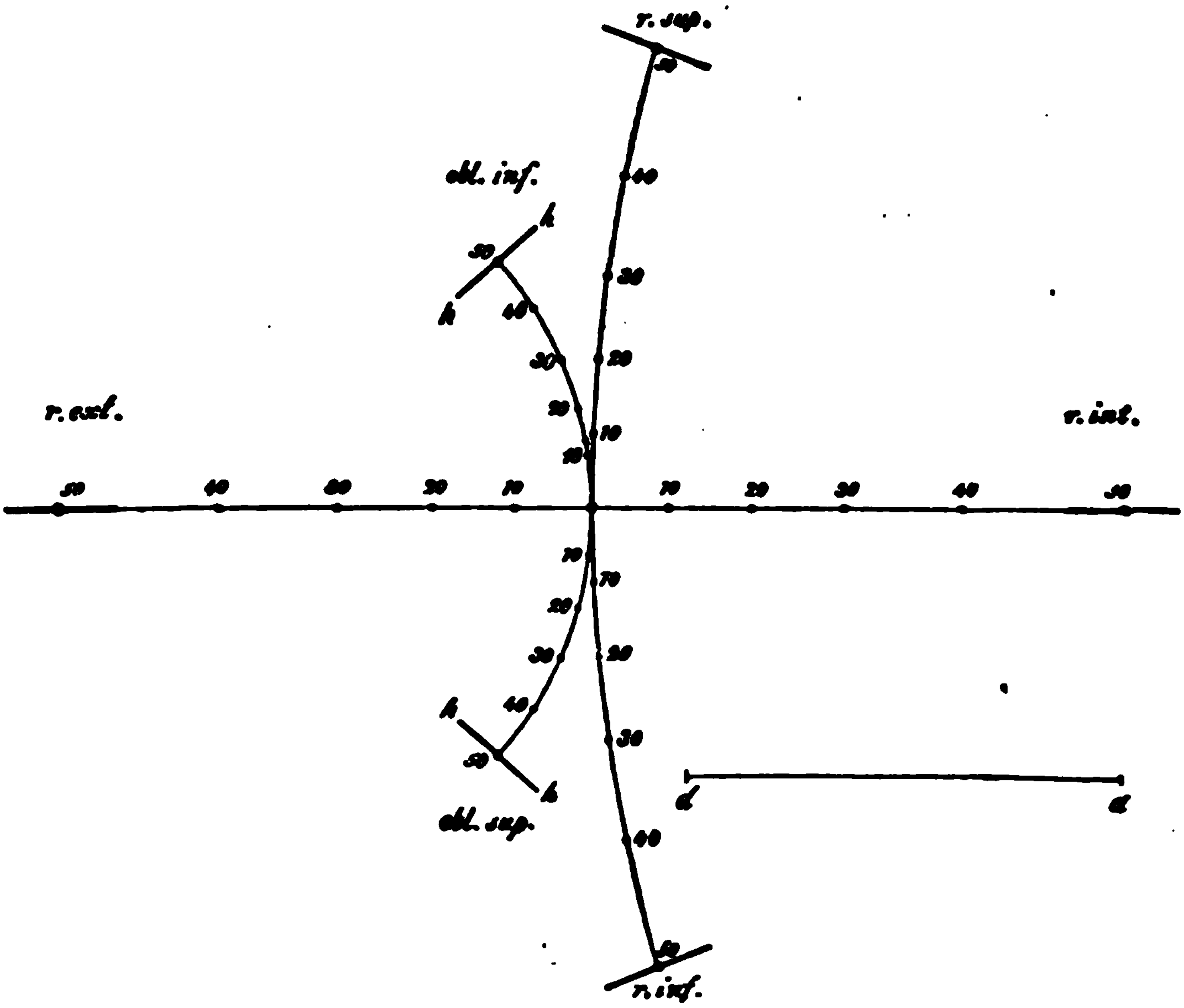



FIG. 73.—Hering's diagram of eye-movements, showing course the eye would follow if pulled by each muscle singly.

ments, one may distinguish certain positions. What is known as the primary position is that which the eyes have when fixed on a distant object in the median plane and a little (15°) below the horizontal. From this, movements may be made in any direction with the optic axes parallel, or the eyes may be converged upon points in the median plane or to one side of it. These positions have been called

secondary and tertiary, but no agreement as to which are to be called secondary and which tertiary has been attained.

**The Two Eyes are One for Vision.** — The fact that we always use two eyes instead of one offers interesting problems as to how two impressions can combine in one, what part each contributes, and the advantages of binocular as compared with monocular vision. In general, it may be said that for most purposes the two eyes act almost as one organ. If a plane surface be presented to both eyes, we see it single and not appreciably different from the same surface as seen by a single retina. When different objects are presented to the surfaces of the two retinas, the result may be that (1) the two may fuse to produce a new quality, (2) one may suppress the other entirely, or (3) first one may be seen, then the other. Colors which fuse when they fall upon the same surface in a single eye are likely to fuse when one stimulates one retina, the other the other. For certain individuals there may be an alternation. Thus, if one half of a stereoscopic slide be red and the other blue, when looked at in the stereoscope they will ordinarily give a purple, but at times and in part of the field an individual will see first the red and then the blue. Where a contour of any kind is presented to one eye and a uniform surface to the other, as in Figure 74, the contours will be noticed and the plain surface neglected. The law may be formulated in the statement that you see what means most to you, what is most interesting, while you neglect the unimportant plain surface. Where two colors or grays, alike except in brightness, are combined, the result is a single color with a brightness intermediate between that of the components.

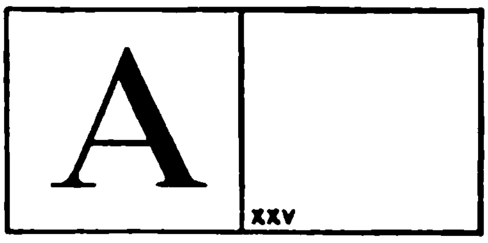



FIG. 74.—Stereoscope slide that shows the effect of contours. (From Titchener, "Experimental Psychology.")

The brightness is usually a little greater than the average for the two stimuli. Thus, when the two are of the same brightness, the brightness of the combined image may be $\frac{1}{10}$ greater than that of either alone, and when they are very different, the brighter may have its brightness reduced by the darker. This latter is known as Fechner's paradox, since the addition of the fainter brightness to the greater reduces rather than increases the brighter. A contrast color may also be induced in one eye by stimulation of the other.

**Corresponding Points.** — Very important for the space problems is an understanding of the arrangement of the points or lines that are seen singly. If vertical lines, one on one half, the other on the other half of the stereoscope slide, be seen in the stereoscope, it will be found that the lines will be seen as one if they are so placed that the images fall on identical points, *i.e.*, on points that are the same distance from the fovea and in the same direction. If both are vertical and pass through the centre of the fovea, they will be seen as one; if one pass through the fovea, the other through a point one degree to either side of it, both will be seen. Identical points may be defined as those equidistant from the fovea and in the same direction from it. If the two retinas could be placed one over the other in such a way that the foveas and the vertical and horizontal axes coincided, then all points that were superimposed would be identical points. Stated in terms of rays of light, those rays fall upon identical points which make the same angle with the lines of sight of each eye and in the same direction. The line of sight is the line from the fixation point to the centre of the fovea. Corresponding points are those points which in practice combine to give a single image. Identical points are defined geometrically. Ordinarily they agree for practical purposes.

A most important problem for the perception of space is to determine how much two stimuli may depart from correspondence before they can be seen as two; or, in terms of our first problem, how far the two lines on the stereoscopic slide may depart from correspondence before they will seem to be two. Pulfrich[1] and Bourdon[2] found that two objects need have no greater deviation from correspondence than from $5''$ to $12''$ for the deviation to be noticed. This is considerably less than the 'limen of twoness' for a single eye. It should be added that the lines are not necessarily seen as two, but the divergence may be translated into depth, as will be seen in a later discussion. Considerably greater deviations from correspondence may take place without being noticed if the lines are horizontal than if vertical.

Why two points should thus give rise to but a single image is not easy to say. The first theory, suggested by Johannes Müller, was that it was due to the fact that corresponding points were connected with the same half of the brain. It is a fact that the right half of each retina is connected with the right hemisphere, and each left half with the left hemisphere. There is, as the diagram (p. 54) shows, only a partial crossing at the chiasma, — half of the fibres cross and half go uncrossed to the same side of the brain. Müller assumed that these fibres in some way combine in the cortex, perhaps connect with the same cells, and so give rise to a single image. This would be the nativistic explanation; the combination would be due to the innate nervous connections. The empiricist, however, can cite numerous cases in which this correspondence is changed by experience. Individuals whose eyes are

[1] Physikalische Zeitschrift, 1899, No. 9.

[2] Revue Philosophique, Vol. 25, p. 74.

badly crossed, who squint, develop a new set of corresponding points; the points that have been used in seeing the same object come to give single images, or else the image from one eye is disregarded. Similarly, horizontal lines may be a considerably greater distance apart than vertical ones and still correspond. Under those circumstances experience makes it more likely that there is one line than two. If the lines be vertical and deviate very slightly from correspondence, they will be seen as two. We shall see that this deviation from correspondence of vertical lines is an important factor in the appreciation of distance, and is therefore noticed; while the necessity for distinguishing horizontal lines is relatively slight. The empiricist's explanation would be that we see the two images as one, because tests by touch or other senses have shown that there is only one object present in spite of the two images; we have learned that two images mean one object, and the positions that are most frequently stimulated together by a single object become corresponding points.

**The Horopter.** — The problems of binocular vision and corresponding points are of interest because of the light that they throw upon the positions that objects in space must occupy if they are to be seen singly. When the eyes are converged in a given position, there is only one distance from which rays of light can fall upon corresponding points. The distance varies as convergence varies, but the locus of points in space which will send rays to corresponding points is strictly limited. Points nearer or more remote will fall upon non-corresponding points and so give double images. The locus of all points that fall upon corresponding points is called the horopter. The form of the horopter has been developed mathematically in great detail. Since the assumptions upon which the com-

putations are based do not correspond accurately to the actual facts of vision, we need pay little attention to the intricacies of the calculations. Two forms of the horopter

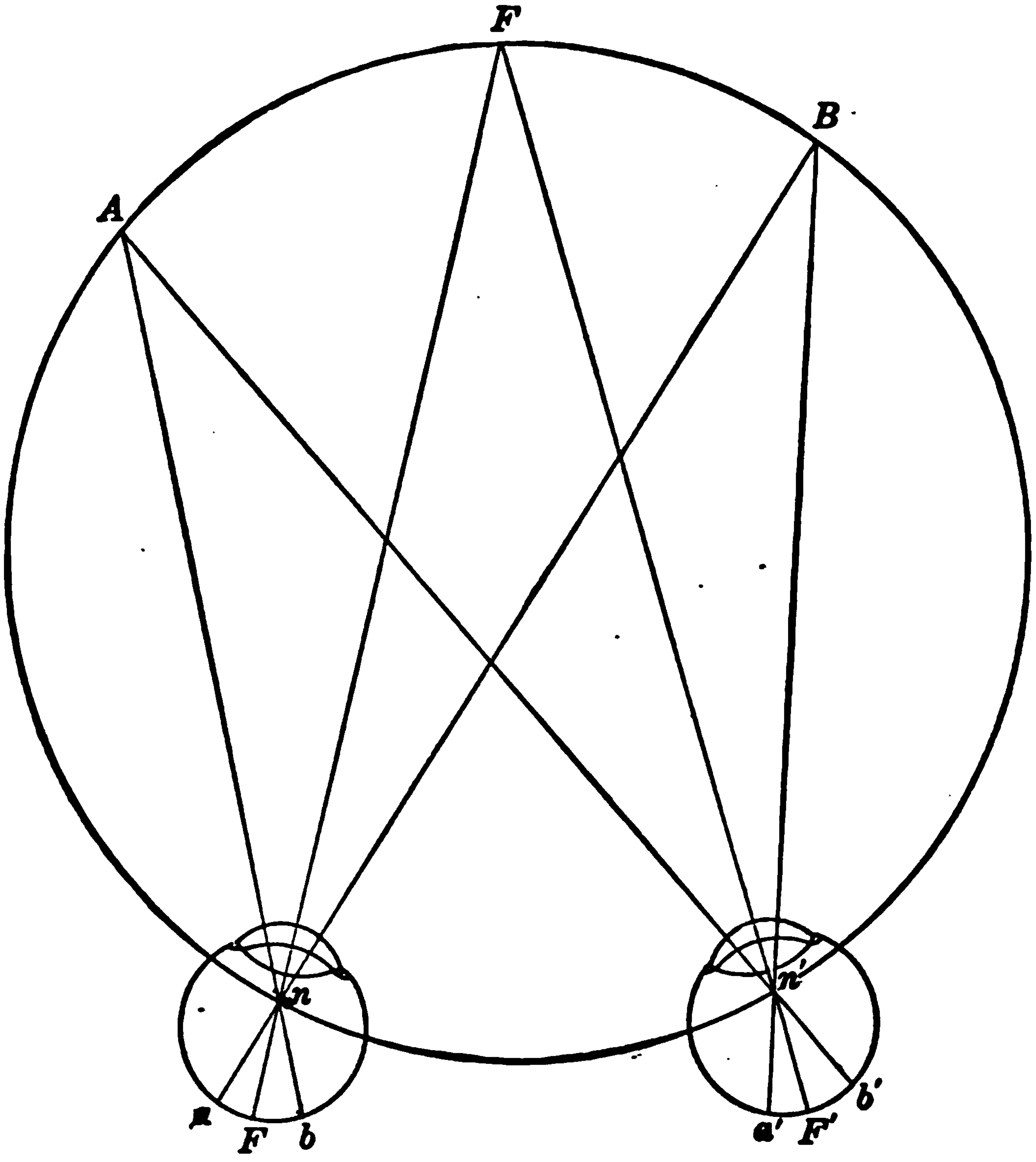



Fig. 75. — Müller's Horopter Circle. *a* and *a'*, *b* and *b'* are corresponding points. Lines drawn from these points through the nodal point will meet in a circle that passes through the fixation point *F* and through the two nodal points, *n* and *n'*.

may be mentioned. When the eyes are converged upon a point in the plane halfway between them, the horopter is a circle passing through the fixation point and the nodal points of both eyes. To this is added a vertical line

through the fixation point. When the eyes are parallel, all points at an infinite distance, the distance at which parallel lines meet, would fall in the horopter, theoretically. In practice, the horopter is composed of all space beyond the point where the departure from the parallel is less than 5″, the least disparateness that can be appreciated, or beyond a distance of some 2500 metres.

**The Perception of Distance.** — We have now to consider the application of the different facts of vision so far collected to the perception of the distance of objects from us, — which may be called depth or the third dimension. We may speak first of the elements which are derived from the structure of the eyes and which in consequence are usually termed the primary or physiological factors. With the single eye the most important is the accommodation of the lens for different distances. As was said in Chapter IV, when a near object is attended to, the ciliary muscle is contracted and this permits the lens to thicken and give a clear image of the object. On the other hand, when a more distant object is attended to, the ciliary muscle is relaxed and the lens is flattened by the tension on the suspensory ligament and so adapted to receive a clear image from distant objects. The degree of strain varies inversely as the distance, and is immediately interpreted to mean the distance of the object. One thinks of objects that are seen with much strain, as near; those that are seen without strain, as remote. (No strain is required for objects more than about 50 feet away.) As is usual in all perception, these factors are not observed in themselves; the distance alone ordinarily comes to consciousness.

**Convergence as a Factor in Distance Perception.** — When two eyes are used for the appreciation of distance, estimates are much more accurate than when one eye is used. If a

man looks with one eye at a landscape, he notices that it appears much flatter than usual. Or if one attempts to put a finger through a ring held sidewise by another, it will be found very difficult when one eye is closed, although perfectly easy when both eyes are open. New factors obviously must be added when both eyes are used. Two of these are important. One is muscular, the movements required to converge the eyes upon a single object. Distant objects are viewed with the eyes nearly parallel and with the muscles fairly completely relaxed. As an object comes

TABLE II

| Uniocular | | Binocular Comparison | |
|---|---|---|---|
| Distance | Limen | Limen | Relative Limen |
| cm. | cm. | cm. | |
| 250 | 12 | | |
| 180 | 8 | 3.5 | 1/50 |
| 130 | | 2.0 | 1/64 |
| 100 | 8 | | |
| 80 | 5 | 2.0 | 1/39 |
| 70 | | 1.5 | 1/45 |
| 60 | | 1.0 | 1/50 |
| 40 | 4.5 | | |

nearer, it is necessary to contract the internal recti muscles that the eyes may be converged to see it with the foveas. This gives rise to another strain that also decreases with the distance. This strain is a more accurate index of distance and can furthermore be used to detect distance over a longer range than the strain of accommodation. If one compare the distance of a thread seen at different distances first with one eye then with both, under conditions that restrict the means of determining distance to the muscular adjustment, it is found that the distances that can be distinguished are much less in the latter case than in the

former. This is shown in the table on page 315 taken from Wundt.

The distance is the absolute distance from the eye; the limen, the difference in distance that can be just noticed; while the relative limen is the limen for binocular vision divided by the absolute distance. This, it will be noticed, is approximately the same as the difference limen for the comparison of horizontal lines on a flat surface, in which movements have also been regarded as an important factor.

**Double Images in the Perception of Distance.** — Still another indication of the distance of objects is given by the differences in the images of the objects on the two retinas. One may be said to get a different image of a distance with each eye. If one hold a ruler end on in front of the eyes and close first one eye and then the other, it will be noted that the image shifts as the eyes are changed. If one converges upon the far end, with both eyes open, the near end will be seen double, while if one looks at the nearer end, the farther will be double. In either case the image of the ruler will slant from the double to the single end. These double images will not be noticed at first but will be used as immediate signs of the distance of one end from the other. Similarly, if two threads are present simultaneously in the field of vision at different distances, the one fixated will be seen single, the other double, and will be separated by a space that increases with the distance between the threads. This doubleness is of value only in determining the distance between two objects or points, not for the determination of the absolute distance of a single object. The degree of doubleness changes with each position of the eyes as well as with the distance of the object. Given the absolute distance of any point of reference, the distance of any other point from that in the field of vision may be determined.

Not only may the distance between two points be estimated in this way but also which is nearer the observer. If one

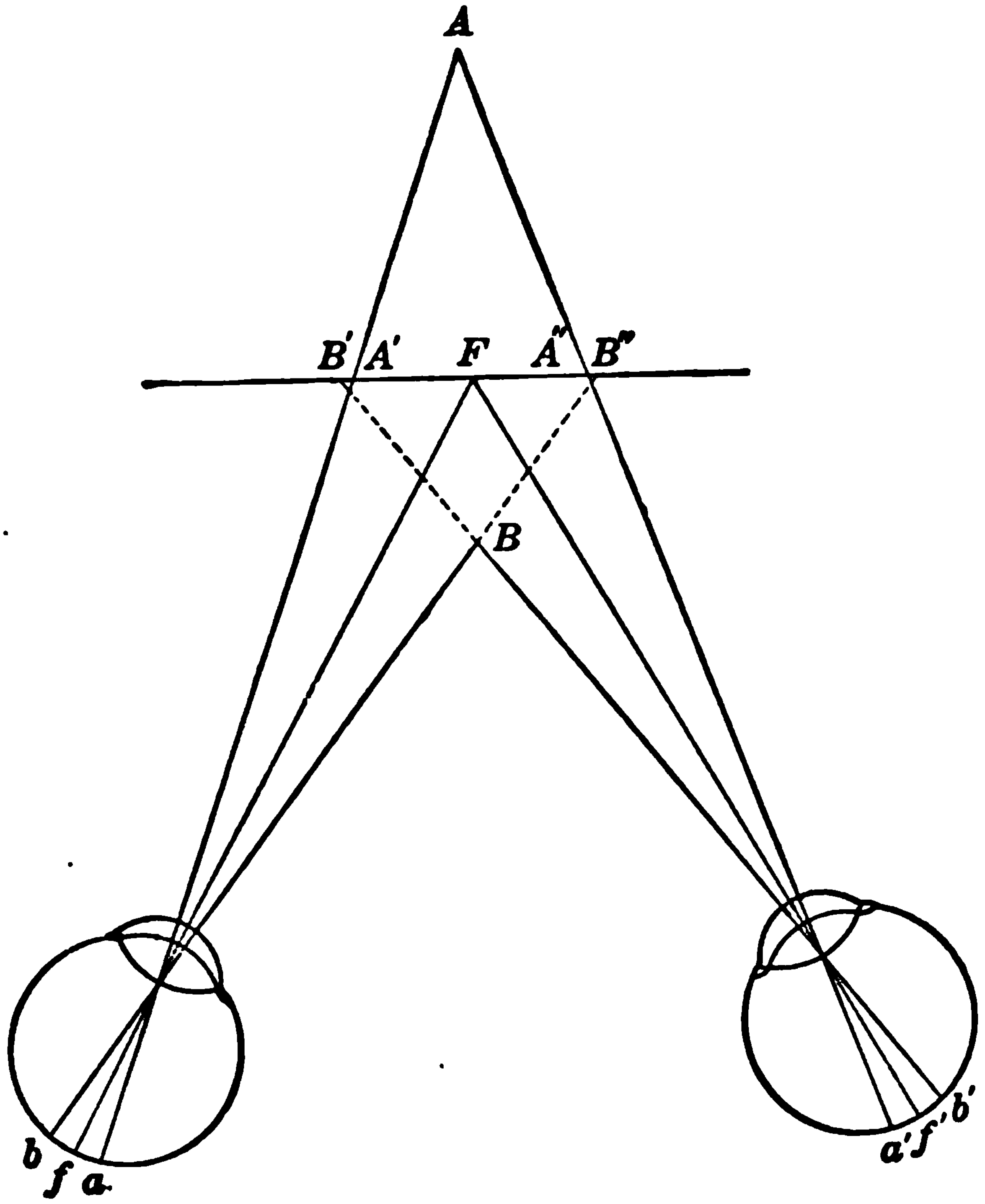



FIG. 76. — To illustrate crossed and uncrossed images. $F$ is the fixation point and is seen singly. An image of a more distant point $A$ falls upon points $a$ and $a'$ on the retinas, which are non-corresponding. As excitations of the retina are projected to the plane of the fixation point, they are seen at $A'$ and $A''$ and are therefore uncrossed, the image seen with the right eye is seen to the right of the fixation point and to the right of the image seen with the left eye. Objects nearer than the fixation point, as $B$, will also be projected to the fixation plane at $B'$ and $B''$ and so are crossed, the image on the right retina is seen as if it were to the left of the fixation point and *vice versa*.

fixate the more remote, the double images are crossed; that is, the one on the right is seen with the left eye, and *vice versa*. If one fixate the nearer, the more remote gives un-

crossed double images. This can be tested by closing one eye. It will be noticed that when the farther object is looked at and one eye is closed, the image on the opposite

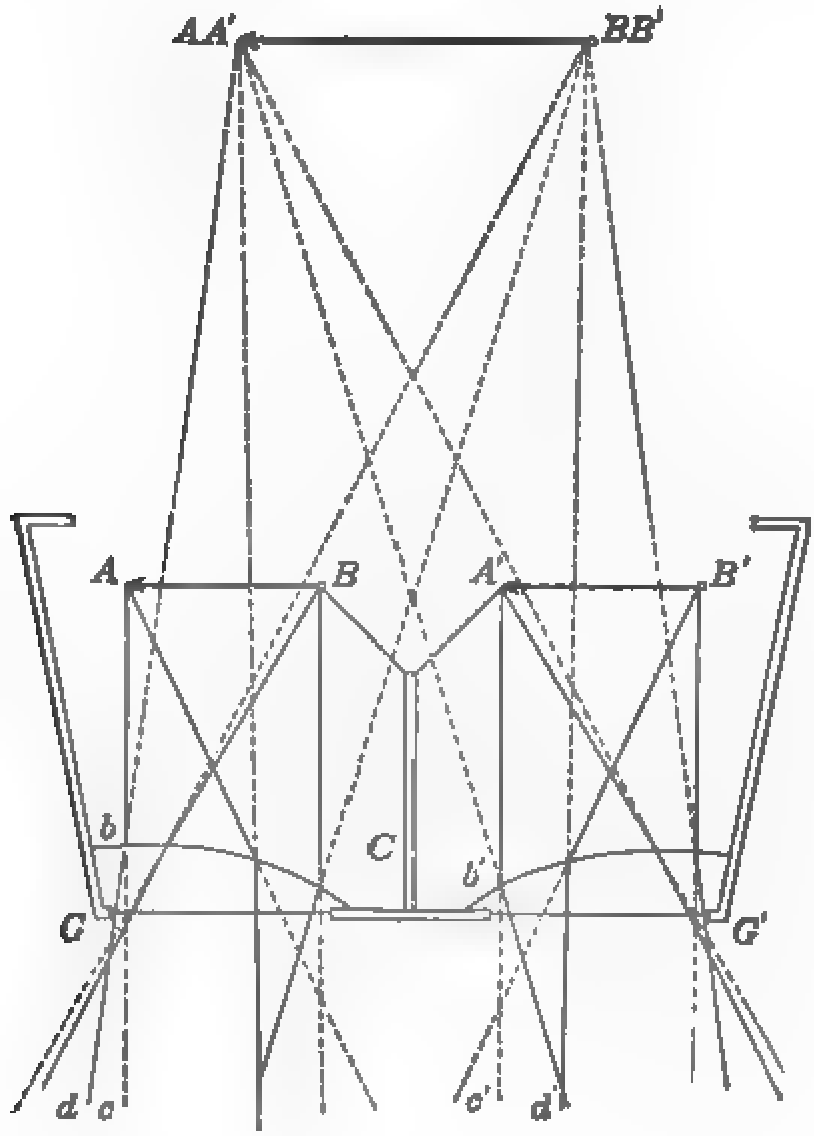



Fig. 77. — Diagram of prism stereoscope. (From Titchener, "Experimental Psychology.")

side disappears; when the nearer object is fixated, the image on the same side disappears. This occurs because the double images are always referred to the plane of the fixation point in considering their relative position as on the right or on the left. This can be seen by study of the diagram (Fig. 76).

These double images constitute one of the important features in estimating depth in our ordinary perceptions. As one looks at any landscape with the eyes converged upon some object in the middle distance, all nearer objects are seen double in crossed images; all more remote objects are seen double in uncrossed images, and the degree of doubleness increases with the distance from the object fixated. These double images are not ordinarily seen for themselves, but are at once translated into distance, just as are the strains of accommodation and convergence. However, they can be noticed with a little practice. So close has become the association between double images and the perception of distance that when letters are printed to appear double, they seem nearer or farther even when viewed with a single eye. The importance of the double images may be shown by the use of the ordinary stereoscope which depends for its effect upon the fact that the two pictures represent the image that would be seen, one by the left, the other by the right eye, were one standing at the point occupied by the double camera when the picture was taken. The prisms in the stereoscope turn the rays of light sufficiently

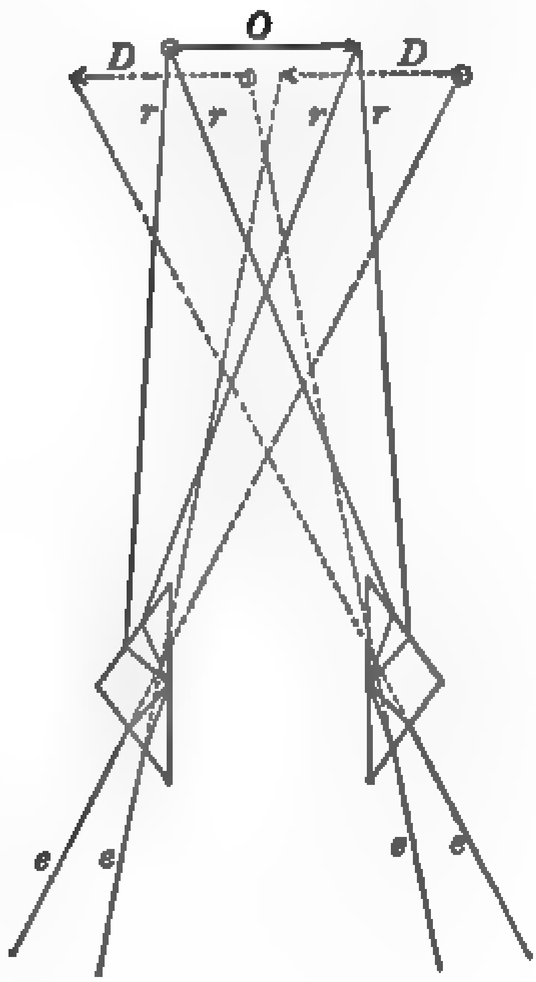


FIG. 78. — Diagram of prism pseudoscope. (From Titchener, *op. cit.*)

to have them enter the eyes as if they came from a single object rather than from two. The difference in the two pictures gives the same degree of doubleness that would be given by the single object, and is interpreted as distance just as it is in actual space perception. Increasing the distance between the cameras that take the pictures, increases the apparent depth.

**Pseudoscope and Teleostereoscope.** — Even more striking is the effect of the pseudoscope. If the relations of the double images are reversed, as may be done in the stereoscope by interchanging the picture belonging to the right eye and that belonging to the left, the nearer objects appear farther away, the more distant nearer than the point of fixation. The same effect may be obtained with real objects by using the pseudoscope devised by Wheatstone. This consists of two right-angle prisms mounted in tubes that can be brought one before each eye. The images are reversed in passing through the prisms, and this makes the images that come from the nearer object enter the eyes as if they came from the more remote; the character of the double images is reversed, those from objects more remote than the fixation point are crossed, those from objects nearer than the fixation point are uncrossed. In consequence, the distance interpretations are also reversed. The inside of a mask when viewed through the stereoscope will appear to be the outside, the nearer of two threads will seem to be more remote, etc. It is to be noted that the effect is much easier to obtain if the inside of the mask be painted to correspond with the design of the outside, and is so lighted as to avoid strong shadows. Another indication of the importance of double images in the perception of distance is furnished by the teleostereoscope. This instrument consists in principle of two pairs of mirrors, *P*, *P*, one

before each eye, and another, *M*, *M*, at a little distance to the outside to receive the rays of light from the object. The effect is to increase the degree of doubleness, and to make the perception of distance as accurate as it would be if the eyes were as far apart as the more widely separated mirrors that first receive the rays of light. The course of the rays may be made out from Fig. 79. A similar device is used in the better field glasses at present. Surfaces of prisms supply the mirrors and these are separated by a much smaller distance to make the instrument more portable,

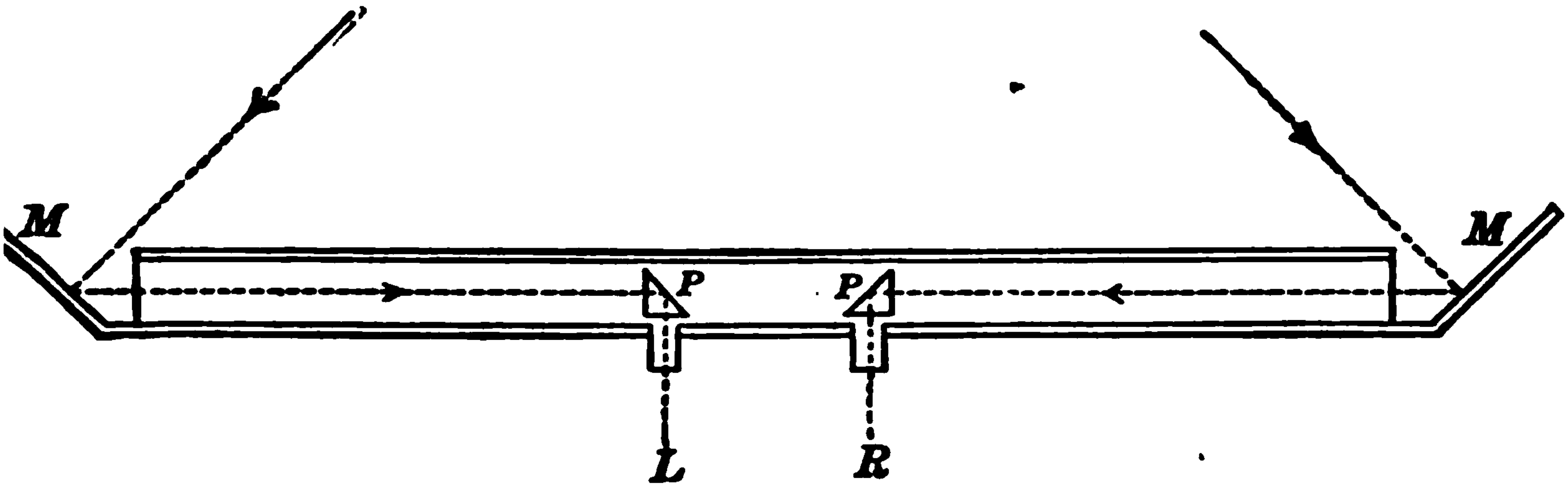



FIG. 79. — Teleostereoscope. (From Titchener, *op. cit.*)

but they serve to increase markedly the accuracy of the estimation of distance.

These three factors, the strain of accommodating the eye to different distances, the strain of converging the eyes upon an object, and the double images, constitute the signs of depth that may be said to depend upon the structure of the organs, and are sometimes called the primary factors. They vary in accuracy, — accommodation is least accurate, convergence about five times as accurate, and double images much more accurate than either of the others. They also vary in the distance at which they are effective. Accommodation is an aid only for objects nearer than fifty feet; convergence is effective up to about 300 feet. Under the best

conditions double images give an idea of distance up to about 2500 yards. Beyond that, the more distant objects show no appreciable doubleness of images, although of course all nearer objects are seen as double. In each case the distance alone is really seen; the strains or double images that have been mentioned are not noticed. The distance directly inferred is not any single mental image or sensation, any more than is the local sign, but is appreciated as distance.

**The Psychological Factors.** — While these primary factors make estimation most accurate, many other signs of distance are of great value. The others consist of changes in the character of the image as the distance changes. They are the secondary or psychological factors. Perhaps the most important of these is perspective. The size of an object is inversely proportional to the distance. If one knows the size of any object in the field of vision, it is altogether possible to infer its distance from its apparent size, the size of the image. The importance of this means of obtaining an idea of distance may be gathered from the use of perspective in art. The distance ascribed to an object in a photograph or painting depends very largely upon its size, relative to other objects in the photograph. Here, as in the other factors, the estimates of distance are not made consciously; one does not first notice the diminished size and then infer how far away the object must be to give that distance, but sees the distance at once, and corrects the size of the object in accordance with his estimate of its distance. The object seems to be of full size and at the correct distance. The tendency to overlook the difference in size is evident from the relatively late development of perspective in art. The early paintings and bas-reliefs make distant objects of the same size as the

nearer ones. Obviously the early artist had not noticed the phenomenon of perspective but inferred distance without knowing how. Even now an artist often draws his distant objects larger than they should be.

A second factor under this head is the higher position of more distant objects in the field of view. Objects on a flat ground plane appear to rise gradually as they go away from the eyes and, with proper allowance for the actual height of the object above the ground plane, the relative height may be used as a measure of distance. This factor was recognized by the early artists. Their distant figures are placed higher than the nearer, an arrangement that makes it possible to show the more remote, as well as to imitate the apparent effects of distance. The haziness or distinctness of objects is also an important factor. This can be seen from the tendency to mistake distant objects for near, where the air is particularly clear. In theatres it is customary to draw a net in front of the more remote parts of the scene. Distant objects appear blue. Both of these effects are due to the absorption of light waves by the air intervening between the object and the observer. The condition is sometimes called air perspective. An element almost too obvious to mention, but nevertheless highly important in practice, is superposition. The partly hidden object must be more remote than the one fully seen.

**Motion an Aid to Distance Perception.** — Motion, both of the observer and of the object, aids in the perception of depth. When the head is moved to one side, all objects in the field of vision are displaced in different degrees. If one is looking at any object in the middle distance, all nearer objects shift in the direction opposite to the movement, all more remote ones in the same direction as the

movement. The amount of the apparent displacement increases with the distance between the object and the fixation point. When one is in rapid motion as in a railway carriage or an automobile and is looking at a point in the middle distance, there is a constant procession of the near objects backward and the more remote objects forward, at a rate that depends upon their distance and the rate of motion. This gives a notion of distance. When objects are themselves in motion, the apparent rate of motion compared with the usual rate of the object at a standard distance serves as an indication of its distance. When seen from a rapidly moving vehicle objects seem smaller than usual because they seem to be moving much more rapidly than usual. This means that they are regarded as much nearer than they really are, and this by the habits of perspective makes them seem small.

**Shadows in Space Perception.** — Another factor that aids in determining the form of objects in the third dimension is the interpretation put upon shadows and high lights. The nearer surfaces are usually well illuminated while the more remote are more or less in the shadow. This is translated at once into depth or distance and the shadows themselves are little noticed. Shadows are much used by the artist; in fact they are quite as important as perspective in enabling him to represent depth in the contour of an object on the flat canvas. In the real object, much depends upon the knowledge of the direction from which the light comes, or from assumptions that are made concerning the direction. If one will look at a cameo under a microscope which reverses the image, it seems to become an intaglio. The high lights fall on the side that they would were the depth relations reversed, and the depth is also reversed. In depressions made in steel by a smooth ball lighted from all

sides to give numerous reflections, it is quite easy to see the depression as a protuberance.

Depth for vision, then, is appreciated by virtue of a number of differences in the sensations that come from the muscles of the eye, external and internal; in the difference in an object as it is seen by the right eye and by the left; and by a number of peculiarities of the image of an object that change with the distance. These sensations are not first seen for themselves and then associated with the idea of distance, but as a result of their presence the object is at once seen at the corresponding distance. In this respect the third dimension is, like the other two dimensions and the idea of position, apparently received immediately, and can be analyzed into its elements only indirectly.

## Auditory Space

**Auditory Perception of Space.** — One other sort of perception of distance needs to be mentioned, the perception of the position and distance of sounds. Unlike tactual and visual sensations, there is in sound no really two-dimensional space, no perception of objects in contact with the sense organ, but merely perception of the distance and direction of objects that give rise to sounds. These localizations are relatively uncertain and indefinite. One is constantly deceived as to the distance and direction of sounds. The breathing of a dog on the hearth may be mistaken for distant thunder or some other intense but distant noise. Front and back are often confused. Right and left much less often; but still under the influence of suggestion, confusions of this sort are far from infrequent. Experiments indicate that the primary factor in the perception of distance is the intensity of the sound as compared with the sound given at some known or standard distance. This implies, first,

a recognition of the source of the sound, then an association between the present intensity of the sound and the distance that would give the particular intensity. A locomotive whistle has been heard at a large number of distances, more or less accurately observed or measured. When it is recognized, its intensity at once suggests the distance. This is true of any familiar sound. If the sound be altogether unfamiliar, appreciation of distance is difficult, although if it be recognized as belonging to some known class, an estimate can usually be made.

**The Appreciation of the Direction of Sounds.** — Perception of direction depends upon three factors, — the relative intensity of the sound heard with each ear, the timbre of the sound, and its intensity. A sound on the left will excite the left ear more than the right. A more accurate notion of the direction of the sound may be gathered from the relative strength of the effects upon the two ears.

Recently evidence has been accumulating in favor of Lord Rayleigh's suggestion that perception of direction depends upon the difference in phase of the tones as they reach the ears. As the tones from directions other than directly in front or directly behind must travel different distances to reach the two ears, they would be in different phases. For example, if the difference in distance were half a double vibration, in length, the tone on the nearer ear would be pulling the drum out while that on the farther ear were pushing the drum in. Usually the difference in phase would not be so great, but always appreciable. Stewart[1] has demonstrated that when tones fall upon the two ears in different phases, the apparent position changes, although the real position remains constant. This is prob-

[1] Stewart, Physical Review, vol. 9, 1917, pp. 502–528.

ably even more important than the relative intensity in determining the direction of the sounding body.

Distinguishing between sounds which come from in front and behind offers greater difficulties. With pure tones it is almost impossible. If two tuning forks of the same pitch be vibrating, one directly in front, the other directly behind, and one be stopped, it is almost impossible to tell which is still sounding. The percentage of mistakes will approach fifty. If the sounds be complex, are noises, or from instruments rich in overtones, fewer mistakes are made. This suggests that the quality of the tone is in some way modified by the direction from which the tone comes. Angell asserts that this may be due to the way in which the various overtones are modified when the tone strikes the outer ear. From one direction, one overtone or group of overtones will be reënforced, from another direction another will be strengthened, and the resulting complex tones enable one to determine the direction. Myers[1] has shown experimentally that changes in the timbre of a tone will induce changes in localization. If a tone be sounded directly in front until the observer has acquired practice in localizing, and then the component parts of the tone be changed to give it a different quality, the sound, although still coming from in front, will be localized in some other position. Myers found, too, that when he placed short rubber tubes in the ears, all capacity for determining the position of sounds disappeared. These tubes made it impossible for the external ear to modify the quality of the tones or their intensity. Changes in the intensity of the sound also induce similar mistakes. The importance of the changed intensities is to be related to the fact that sounds from in front are caught by the pinna, the outer ear, and focussed into the

[1] C. S. Myers, Proc. Royal Society. B. vol 88, 1914; pp. 267–284.

meatus, while sounds from behind are diminished in volume. When the absolute intensity and the distance of a sound are known or may be approximated, the position of the sound as in front of or behind the plane of the ears can be appreciated in terms of intensity. Direction of sounds, then, is appreciated by means of the relative intensities of the tones as heard by the two ears, and by the timbre and intensity of the tone. It has at times been assumed that direction might be known by means of the stimulation of the skin in the neighborhood of the ears, or on other portions of the face. This assumption is improbable in itself, since sound waves are not sufficiently intense to excite the organs of pressure.

**The Auditory Space of the Blind.** — Auditory appreciation of space plays a much larger part for the blind, who must trust to the ears for a knowledge of the position of all distant objects. A blind man appreciates the distance of objects fairly accurately through the effect they have upon the quality of familiar sounds, such as his footsteps or the tapping of his cane. Large objects reflect the sound, give echoes, or modify its quality. It is easy to distinguish the difference in the voice when speaking in a room filled with people and when speaking in an empty room. Even the presence of furniture in a room in an ordinary dwelling has a pronounced effect. The blind man learns to distinguish all of these differences and to learn what they mean as to the presence and arrangement of objects. That the blind depend upon the reflection of sounds in avoiding objects was shown by Dr. Heller,[1] director of a blind asylum, who on one occasion provided his pupils with felt slippers in place of their heavy shoes and watched them at their play. He found that they no longer avoided obstacles

[1] Heller, Studien zur blinden Psychologie.

and would come into conflict with many of them. The sound from their footsteps could no longer be heard sufficiently for the modifications by the obstacles to be noticed. It seems, then, that for the blind much of the perception of space depends upon the modification of the sounds of the footsteps and of other familiar sounds, by walls and objects in general.

## Illusions in Space Perception

**Optical Illusions.** — Very interesting as illustrating the factors that lead to the perception of space and of perception

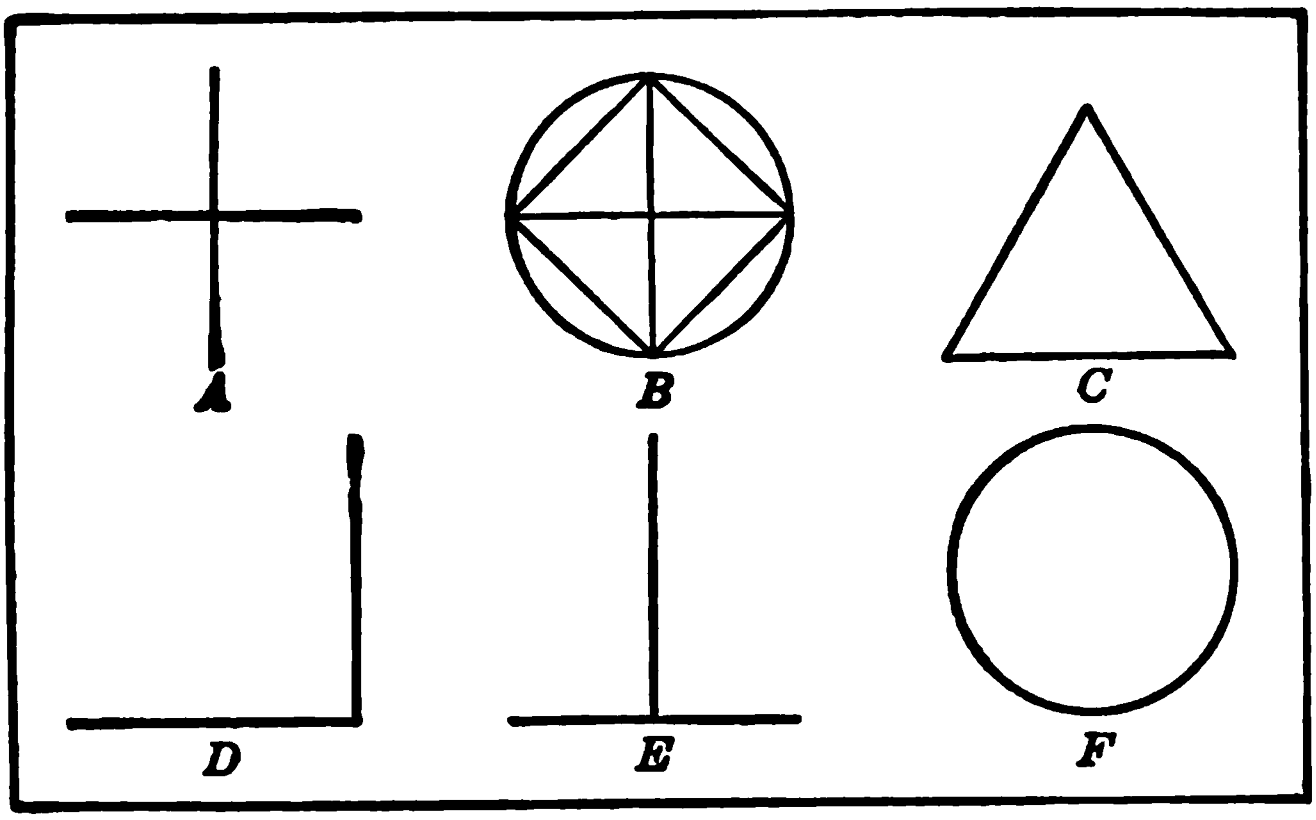



Fig. 80. — Illusions due to overestimation of the vertical. (From Titchener, *op. cit.*)

in general are certain illusions of visual space perception. Many more forms of optical illusion are known than we can describe, and more explanations have been offered than we have room to mention, but we may select a few illusions as illustrations of the more important theories. One of the simplest types is seen in mistaken estimates of the length of lines, or distances between dots. Thus horizontal lines seem shorter than vertical lines of the same length (Fig. 80, *A*, *D*); interrupted spaces seem longer than uninterrupted

or unfilled spaces or lines. Figure 81, *A*, *B*, indicates that filled space, space filled with a number of dots, or a solid line seems longer than the empty space of the same length; Figure *E*, that a square with numerous vertical lines drawn

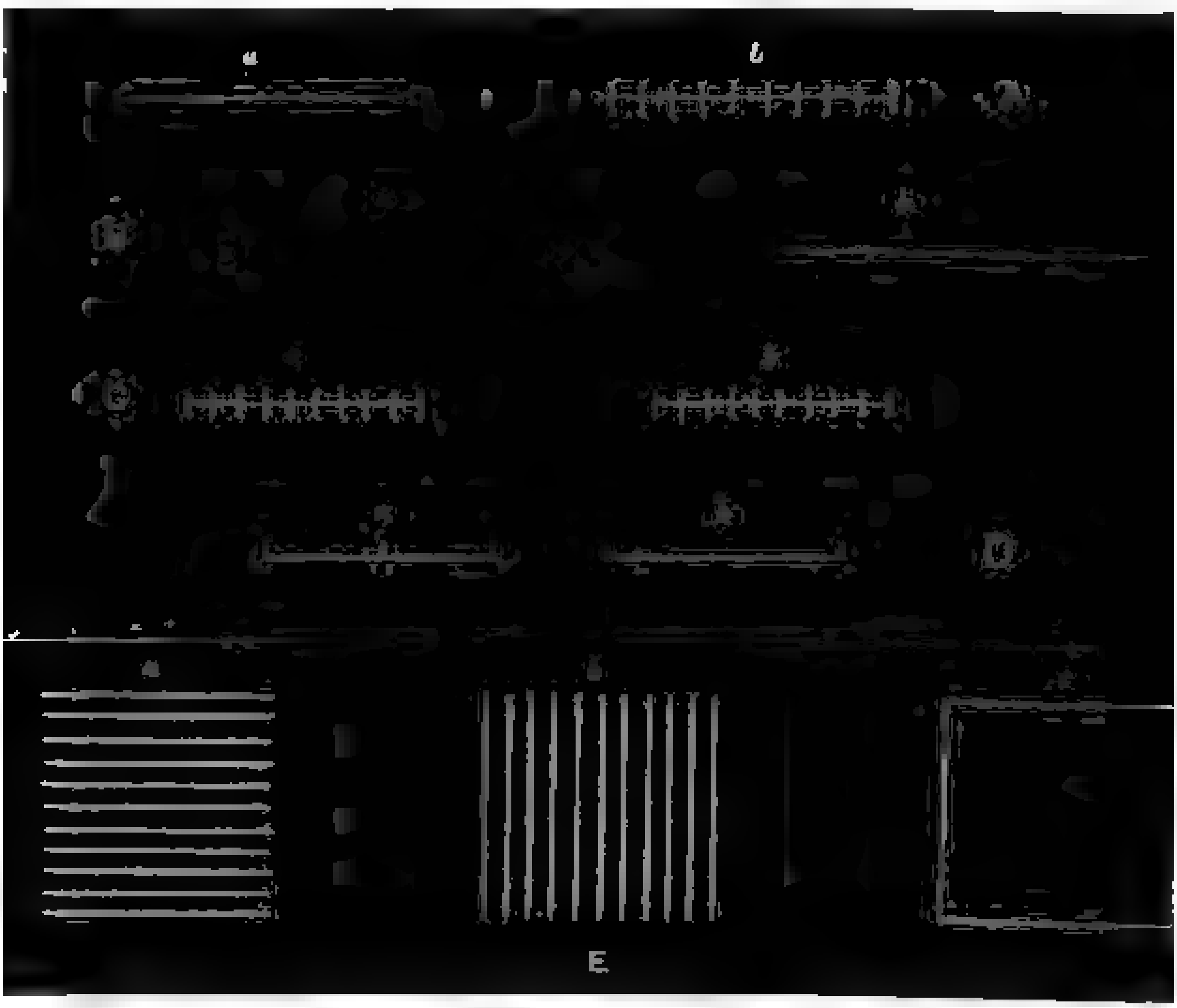



Fig. 81. — Illusions of filled and empty space. (From Titchener, *op. cit.*)

across it seems longer than it is high. Even these simple illusions have given rise to much difference of opinion. One theory would explain all in terms of eye movement. It is said that the fact that the up-and-down movements of the eyes involve a waste of effort, owing to the tendency of each superior and inferior rectus muscle to pull the eye in as well as up, a tendency which must be counteracted by

the oblique muscles, and so give rise to greater amounts of strain, leads to the overestimation. Experiments made with the observer lying on his side which show that the vertical distance is still overestimated would tend to disprove this theory. Helmholtz suggested that the overestimation of the vertical was due to a habit derived from the use of perspective. Vertical lines in space, as in a picture, usually or frequently represent greater horizontal distances seen in perspective, and so we form the habit of overestimating all vertical lines.

According to one theory the interrupted spaces are made to seem longer by a similar exaggeration of the apparent movements through the numerous stops that are made at each of the intervening dots or lines. That this is not the whole story can be seen from the fact that where the dots are relatively few (Fig. 81, *D*), one or two only in the length of the line, the distance is underestimated rather than overestimated. The other explanation is that the filled spaces give an impression of multiplicity and this is confused with the length of the line. The apparent shortening of the line when only one or two dots are inserted is seemingly due to a confusion between the separate spaces and the total length. The full line tends to be compared with the smaller divisions of the divided line. This same confusion is better illustrated in the comparison of the vertical and the horizontal lines in Figure 80, *E*. Here the vertical is compared with the halves of the base line. Where erected at the end of the line, the vertical is slightly overestimated but relatively very slightly (Fig. 80, *D*). This effect can be eliminated by turning the book ninety degrees, while the illusion in *E* persists.

**The Müller-Lyer Illusion.** — One of the most striking and most discussed of all is the Müller-Lyer illusion. It will be

noted that the line, bounded by oblique lines that turn in, seems much shorter than the other line of the same length bounded by oblique lines that turn out. The explanations offered for this illusion include practically all that may be offered for any. Wundt suggested that it was due to eye movements, that the eyes were checked too soon by the

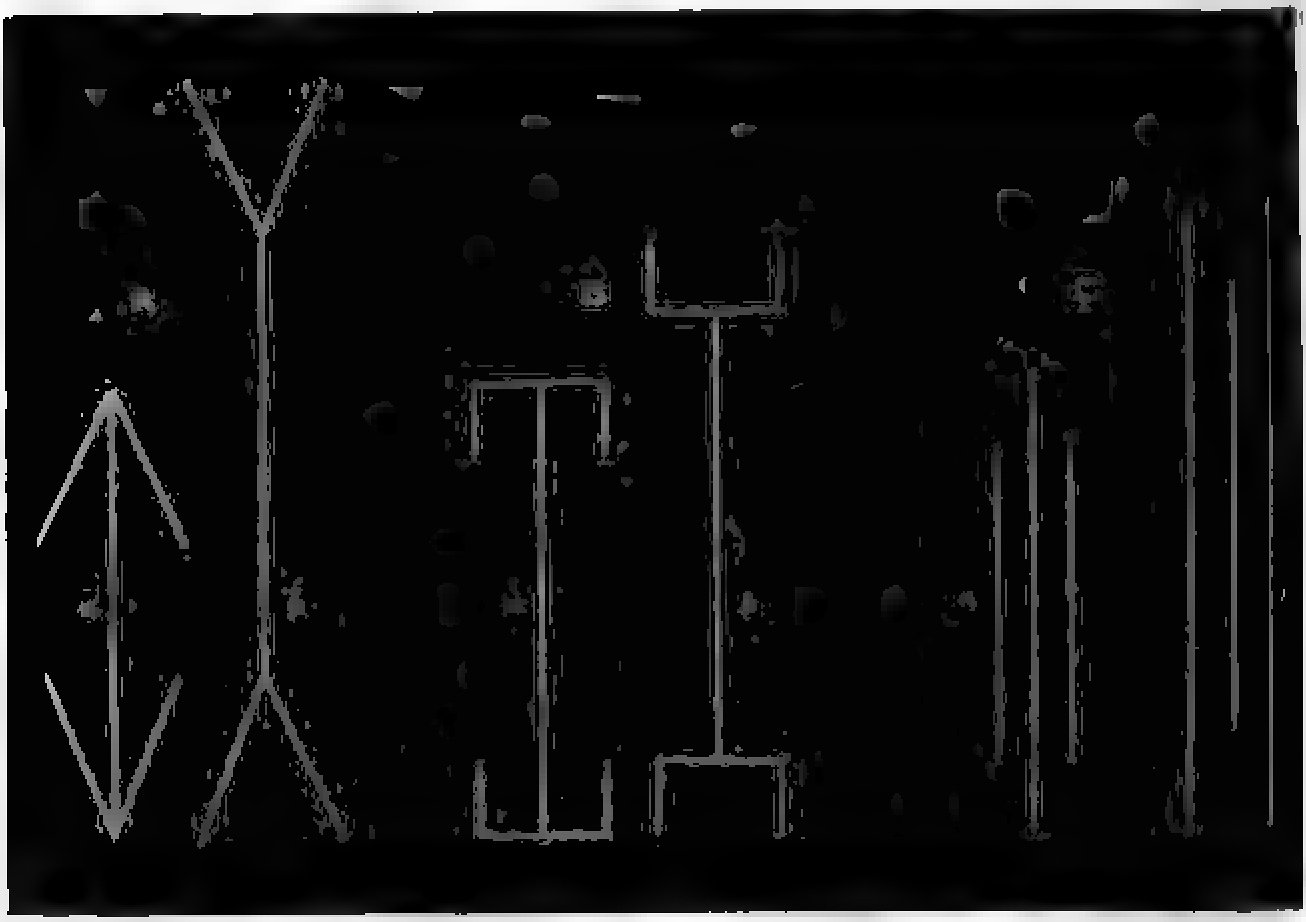
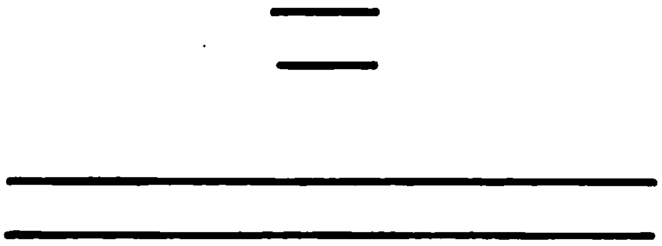


Fig. 82. — Various forms of the Müller-Lyer Illusion.

lines that turn in, and carried on by the lines that turn out. It is suggested that it can be explained on the basis of perspective; that one represents an open book or similar figure with the back towards the observer, the other an open book, much larger, with covers opened towards the observer. In the first case the actual length of the book is the length of the line itself; in the other, the length would be from the end of the oblique lines at their greatest separation. Still

another theory is that one confuses the whole spaces between the oblique lines with the horizontal lines and really makes a judgment of the spaces, although it is assumed that the lines are being compared. This is one application of the so-called theory of confluxion and contrast. It is an instance of the confluxion phase of the theory, *i.e.*,



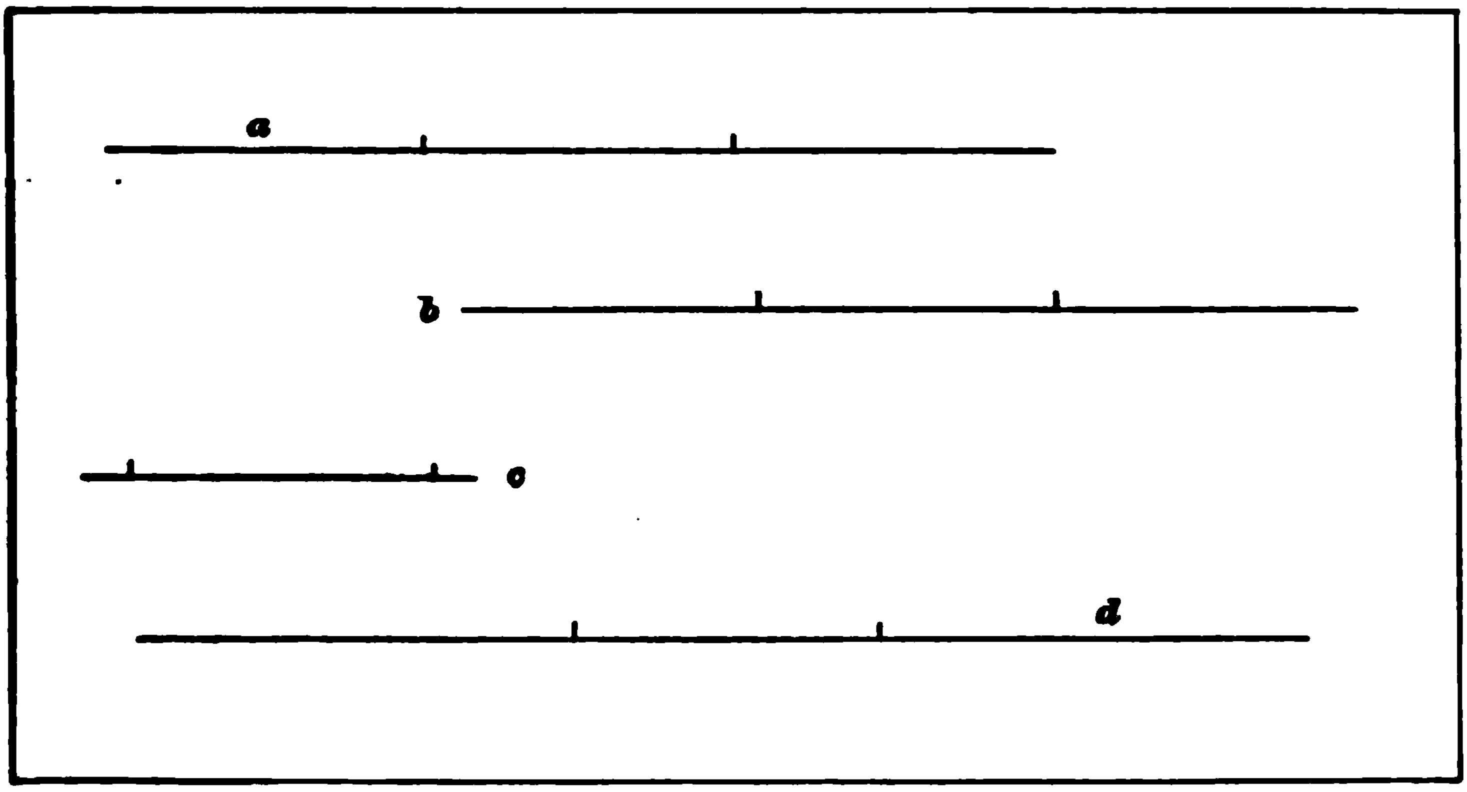



Fig. 83. — Contrast illusions. (From Titchener, *op. cit.*)

of the tendency to confuse something in the surroundings with the part of the figure that is to be judged.

The eye-movement theory is in this case rather far-fetched. Dawes-Hicks found that the illusion persisted when the figures were exposed for too short a time to permit the eyes to move. And while Judd found that moving pictures taken of the eyes while the figures are being compared showed movements that in many instances correspond to the illusion, he concluded that the movements are

due to the illusion rather than the illusion due to the movement. The perspective theory serves to correlate a number of different illusions, and perspective may have some influence, but it is hardly to be regarded as the only explanation.

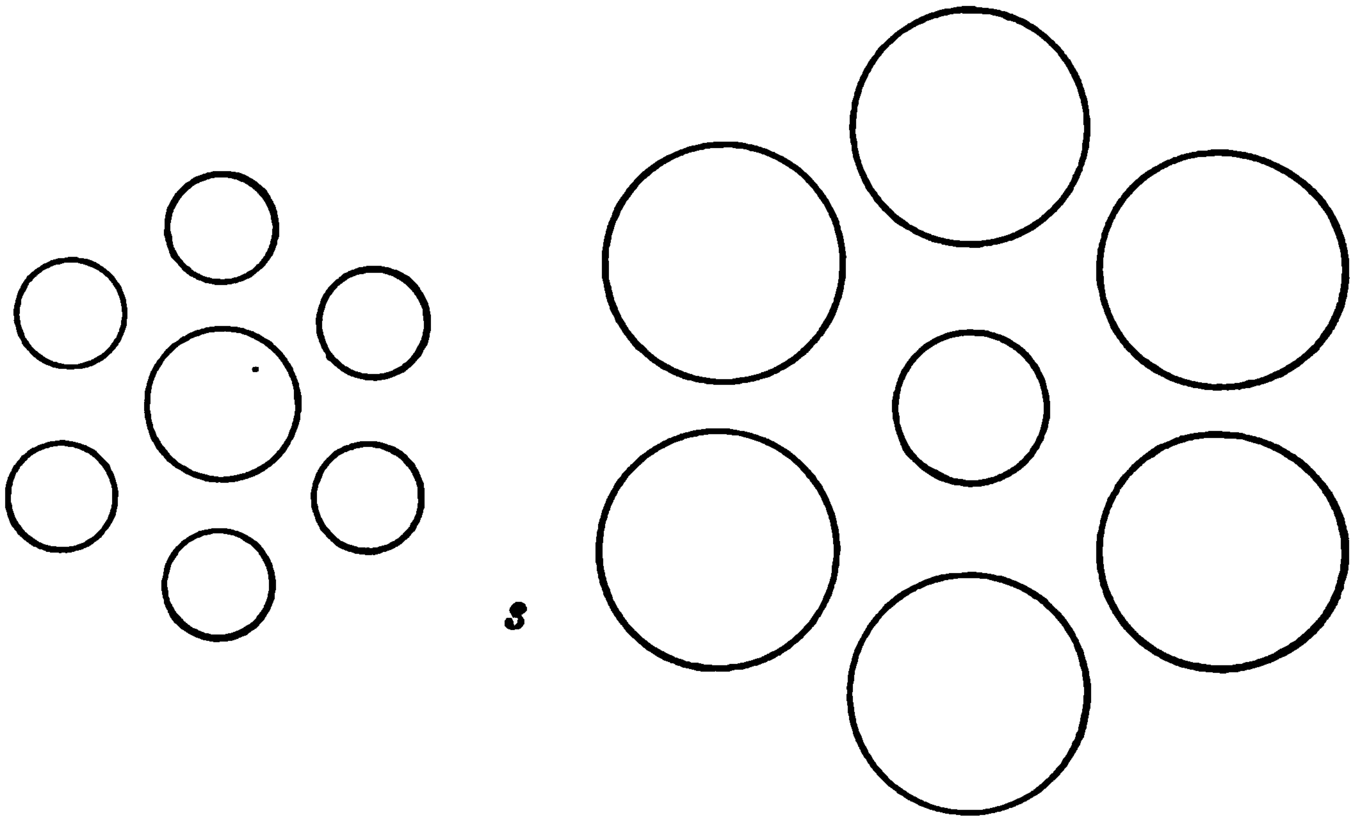


Fig. 84. — Contrast illusions. (From Titchener, *op. cit.*)

In a wide sense, the confluxion theory comes to mean that factors, other than those immediately compared, play a part in determining the comparison, and in this form, it would include the perspective element as well as any other

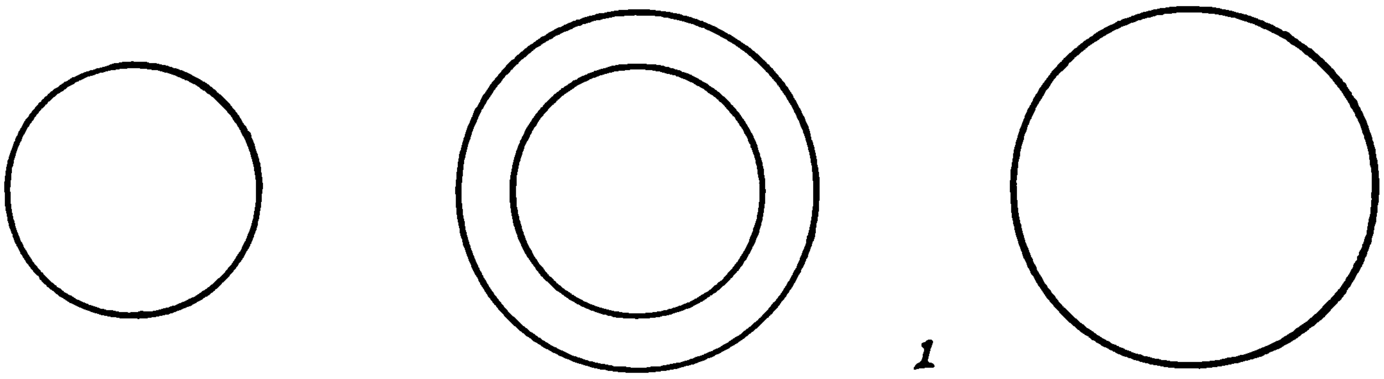


Fig. 85. — Illusion due to confluxion. (From Titchener, *op. cit.*)

considerations which might aid in controlling the judgment. On the whole it more nearly corresponds to the facts.

Illusions of size that illustrate the effect of contrast are seen in the lines of Figure 83 and the circles of Figure 84.

The distance between two short lines seems much longer than one of the same length between two long lines. Much the same effect is obtained with the circles. In Figure 85, when the two circles are put together to form a band, the one seems larger, the other smaller, than when separate. When together, the observer confuses each with the center of the ring, and so tends to judge each as the average between them (confluxion). When a circle is surrounded by a series of very small circles, its size seems to increase as compared with the same circle near a single much larger one (contrast). (Fig. 84.)

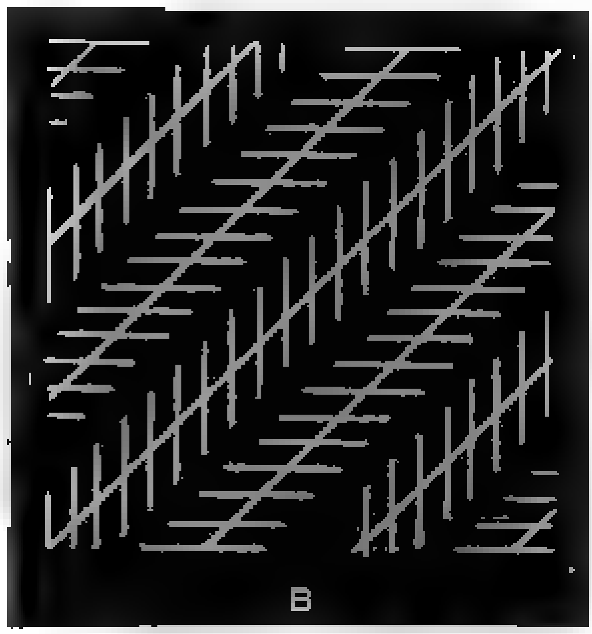


Fig. 86. — Zöllner's Illusion. (From Titchener, *op. cit.*)

**Angle Illusions.** — Illusions of direction are also numerous. They may be illustrated by the Zöllner illusion (Fig. 86), the Hering figure, the Wundt figure (Fig. 87, *A* and *B*), and the Poggendorf figure (Fig. 88). The eye-movement theory, the perspective explanation, and confluxion have all been used as explanations. The eye-movement theory holds that the eyes are distracted by the cross lines; but why they should be is not made particularly clear. The perspective theory may take two forms. Each of the first three figures may be seen as if drawn in perspective; and, inasmuch as the parallel lines do not converge as they should to harmonize with the perspective, it is assumed that they must diverge. Still another application is that the whole figures may be explained as due to the overestimation of

acute angles and the underestimation of obtuse angles. It will be seen that this is what really happens in each case. But it may be said, in addition, that the estimation of the

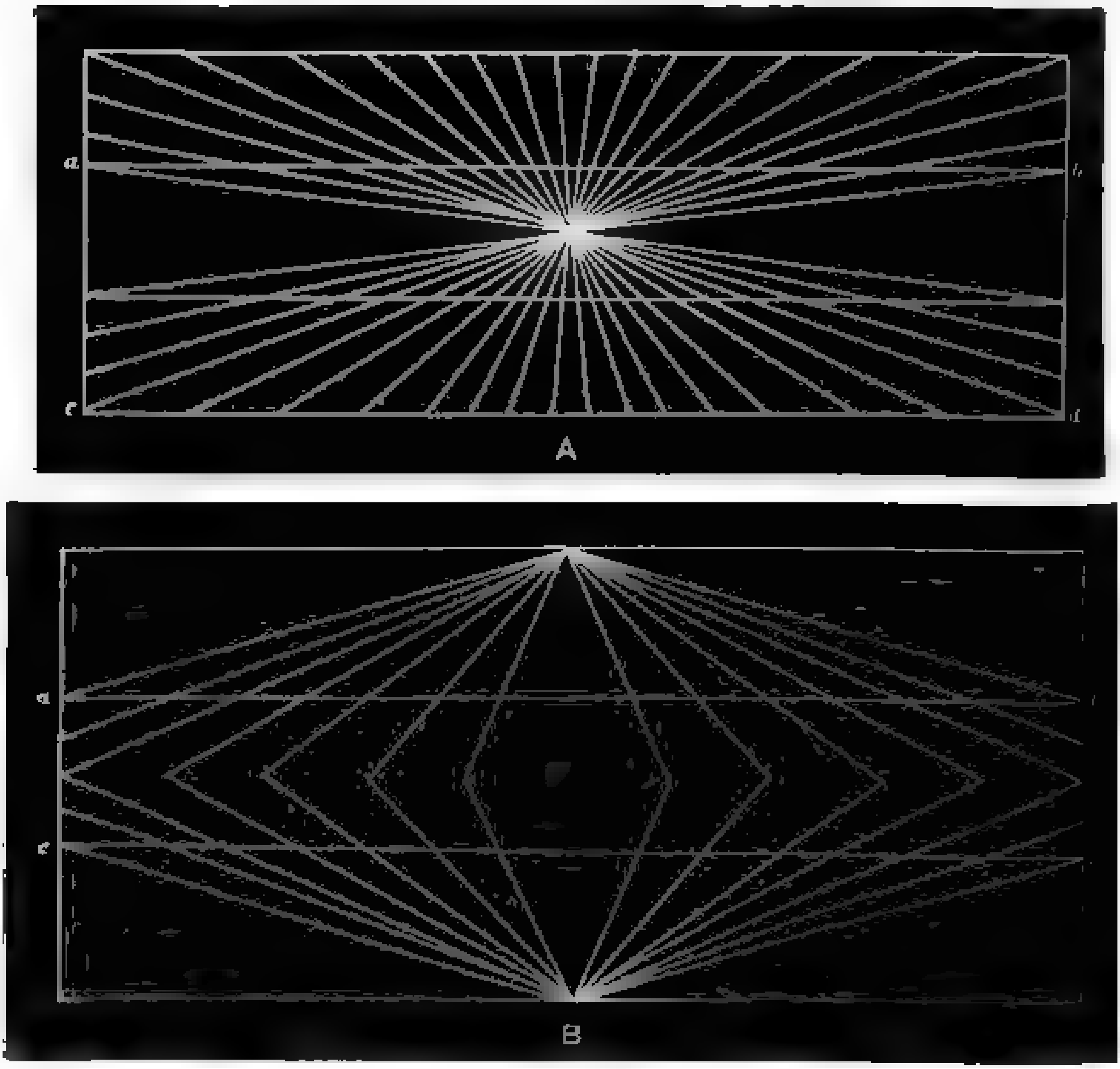



FIG. 87 — Hering's and Wundt's figures. (From Titchener, *op. cit.*)

angles is made on the assumption that whenever two lines cross at right angles and are distorted by perspective, the figure represents two lines crossing at right angles as seen with the horizontal line in an oblique plane. This can be made out in Figures 89 and 90, where the two lines can

easily be imagined to represent two lines crossing at right angles. Since all angles made by straight lines are likely to indicate right angles seen in perspective, we have acquired the habit of overestimating acute and underestimating obtuse angles. The Poggendorf illusion readily falls under this explanation. The lines do not meet, because each is turned toward the horizontal; and they are turned toward the horizontal by the overestimation of the small angles; or to go back to the explanation of that tendency, one inclines to see it as if it were really more nearly perpendicular to the vertical line.

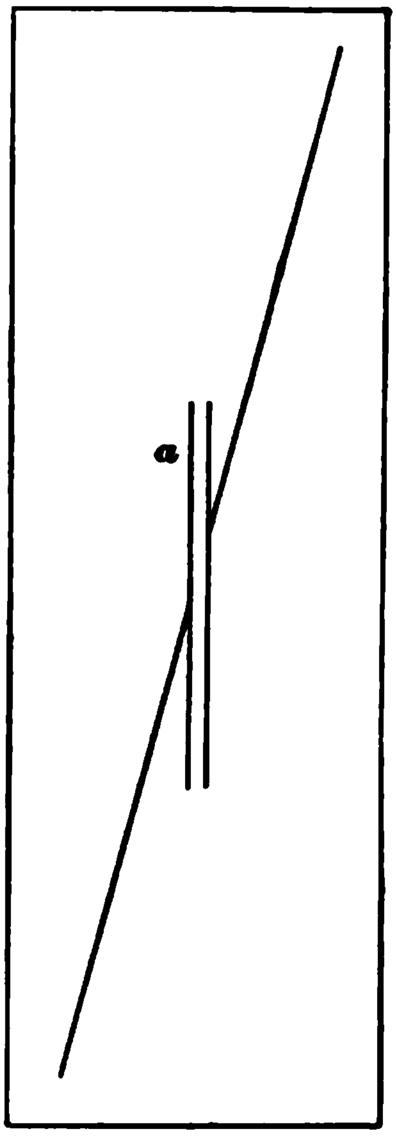



Fig. 88. — Poggendorf's Illusion. (From Titchener, *op. cit.*)

These illusions, then, are all due to the fact that interpretation tends to become mixed with sensation, and that one cannot keep attention fixed exclusively upon the essentials of the figure, but is misled by its surroundings. Mixed with the confusion of part with the whole, we always find the tendency to see what the figure means rather than the figure itself, and to believe that it means something different from what it actually represents. The various special theories, perspective, confusion, or confluxion, even eye movements, are but special forms of this general tendency.

**General Theories of Space Perception.** — A more abstract problem naturally arises at the end of a statement of the particular facts of space perception, — the question, what is the idea of space itself. Two schools have contended over this question since the beginnings of modern philoso-

phy. One, the nativistic school, insists that the capacity to appreciate space is born with us, and may be used without preliminary practice. It may be dependent upon inherited characteristics of our nervous system, or may be an original mental activity. The other school, the empirical, asserts that the notion of space is developed through experience, — must be derived in some way from the conditions of

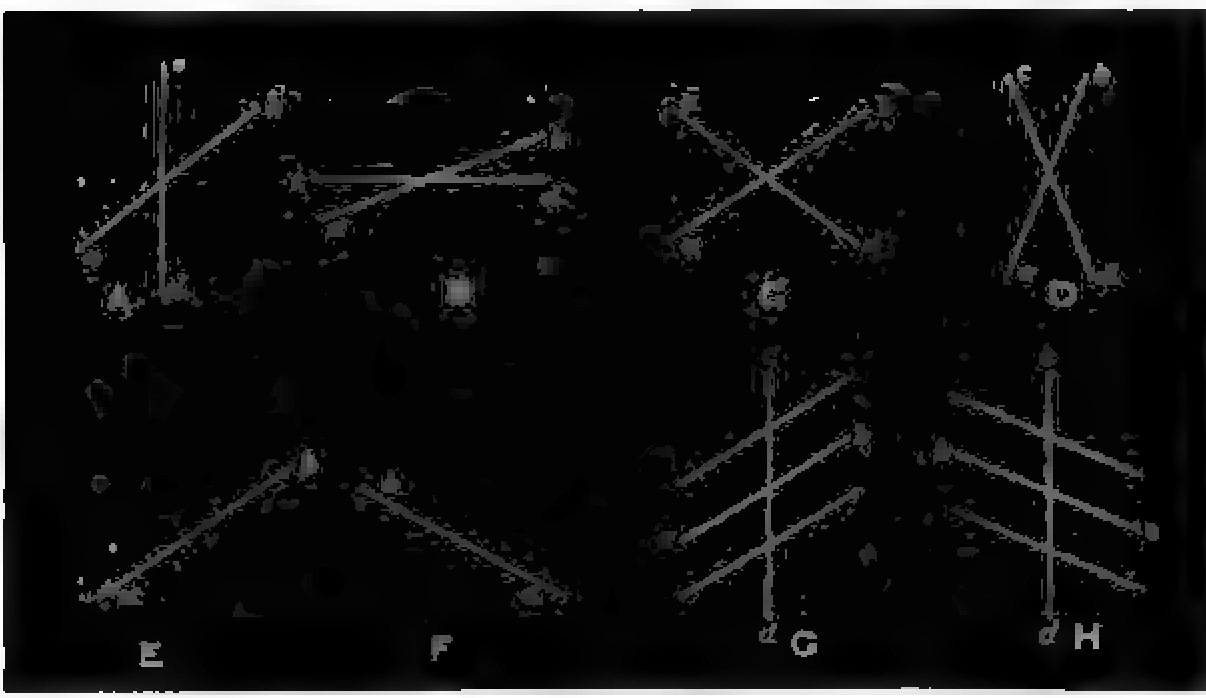



FIG. 89. — Hering's angle illusions. Careful observation shows that any of the oblique lines may be interpreted as crossing in some other than the plane of the page. (From Titchener, *op. cit.*)

perception. For the nativist, space offers no problems; it is appreciated at once, as color is appreciated. For the empiricist, it is necessary to discover the components of the space idea and also to determine how a particular space idea is suggested. The concrete evidence for neither position is conclusive. The empiricists point to the numerous cases of error in judgment, and the cases in which appreciation of space may be shown to depend upon definite sensations and particular associations. The nativist contents himself with the statement that the factors which according to the em-

piricist compose space are altogether different from space as we know it, and also that it is inconceivable that space can be derived from anything not itself spatial.


FIG. 90. —The transformation of right angles in natural objects seen in perspective.

**The Space Discrimination of Those Born Blind.** — The problem cannot ordinarily be approached directly, since the child has already developed his notion of space before he is able to tell us about it, and adults when questioned will have long forgotten what their first experiences were like and how they developed spatial ideas. As early as the seventeenth century, Locke suggested that if one could find a man who had been born blind and recovered his sight after he became able to describe his experiences, it would be possible to say how much of space perception was innate and, if it proved not to be innate, how it was acquired. Since then a fair number of cases of this sort have been observed. The lens of the eye is occasionally opaque from birth and may be removed by an operation, and the patient be made to see. There is no great agreement as to what the patient can see, but the following statements seem to be in harmony with most results. The shape of objects is not recognized at all. One patient could not tell a square from a circle until he had had a chance to touch each. The field of vision is described as a confused mass in which everything seems to be in irregular movement. Some patients are said to notice the difference between geometrical figures when they cannot say in what that difference consists. One, after being told what an angle was, could count the angles on a figure and thus distinguish a triangle from a square, but for some time after-

wards was not able to distinguish without this counting The perception of distance was defective in each instance. Objects seemed in most cases to touch the eye, and in no case were they projected beyond the reach of the patient. There is practically no appreciation of depth. When all the evidence has been assembled, neither school is altogether convinced of the falsity of its own position. The nativist argues that the patient sees so little, because he transfers the associations developed by touch to sight. The patient thinks objects must touch his eyes because they touch his skin. The empiricist, on the contrary, argues that the patient would see nothing were it not for this same earlier experience, that interpretation from tactual experiences and from the light that comes through the lenses before the operation makes possible even such imperfect spatial judgments as are made.

The attempts made by the empiricist to explain or analyze the spatial experience have for the most part consisted in reducing the various forms into some single one. Movements or memories of movements are most frequently asserted to constitute the essential idea of space. Double images, according to the theory, give an idea of depth because they call up the memories of old movements of convergence or of the reaching movements required to obtain the object. That such transfers from one sense to another do take place is readily observed. Most persons use a visual space, although a motor-minded individual may translate visual and tactual distances into kinæsthetic terms. But, after all, translation from one space to another does not solve the problem of space. No one sense gives a more direct and intuitive knowledge of space than any other. Vision is probably more delicate in its appreciation, while movement demands an accuracy in space es-

timates to be adequate; but it cannot be said that the accuracy of the one or the needs of the other constitute it the intuitive space sense.

We may reduce the problem of the origin of space to its lowest terms, if we see that there are three essential elements in the spatial experience. These are the sensation or sensory cue, the idea or notion of space, and the association between them. Some sensory cue must always be present to suggest the idea. Contact on a spot calls up the idea of position; double images, strains of accommodation and convergence arouse the idea of distance. The question as to what is innate and what derived from experience, may be considered separately for each of these cases. We may assert at once that the connection is derived through experience. Illusions show that the associates may be misplaced — the wrong idea may be called up by any cue — and an innate capacity to make mistakes is not desired by the most ardent supporters of a nativist theory.

That the exciting cause of all perception, a bare sensation or sensory stimulus, depends upon the physical structure of the sense organ or the nervous connections, and to this extent is innate, no one will deny. The case for the idea is not so clear. Whether this be innate or derived is the real crux of the problem. The argument that it is derived must give over any attempt to reduce it to a single element or even to a combination of different elements which preserve their original character. Space cannot be movement, it cannot be sight or touch. Judd has suggested that it is not a movement but an organized system of movements in which the various contradictions have been removed and suited to all possible occasions for action.

**Space an Integrating Concept.** — If we accept this statement as far as it goes, we must add to it that space is an organization of experience as a whole, sensory as well as motor; and that there results from it not movement, but a concept or notion which not merely prepares for action but makes it possible to represent all spatial experiences consistently and harmoniously. We may use it for our estimates of space, as well as in the control of movements, — for the combinations of the mathematician as well as for the actual structures of the engineer. What the actual content of this idea is cannot be asserted. Like most concepts, it is more important for the things it represents than for itself. It probably varies in many respects from individual to individual. It is certainly more highly developed for the mathematician than for the common man, and more highly developed for the adult than for the child, for the civilized man than for the savage. The process of development has probably been to accept some simple idea or even sensation, and to use it until contradictions appear. These contradictions are obviated by changing the notion until something that avoids the difficulties is hit upon, and this is again changed as occasion arises. The concept always grows out of practical needs, whether sensory or motor. Thus images on the retina are given a size that can be most readily fitted into our conception of the field of vision as a whole. Small objects are usually seen as if they were at about arm's length or where they can be easily manipulated, houses at a distance that gives us a good view of them; and, in thought, these various typical distances or sizes are used in place of the sizes of the images on the retina. They are what are called the real sizes of the objects. Similar notions develop for position, for extent, and for depth. They are changed and adjusted

until they satisfy the conditions of movement, of sight, and touch, and of the practical and theoretical needs of every sort. In the final concept, little if any trace of the particular ideas need be left, certainly nothing that can be analyzed out of the concept by direct introspection. It represents the various experiences as corrected by different tests, but it is not compounded out of them. Our choice as to the real nature of space lies between these alternatives: the assumption, on the one hand, that it is a concept that has developed out of experience by innumerable trials that finally give rise to a system of ideas which satisfactorily represents space; and on the other hand, the nativist position, that an appreciation of space is given once and for all, and that we certainly cannot explain it; we can at most watch its development. The former explanation seems to the writer to offer the possibility of a real explanation; the latter gives up the problem as insoluble.

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# CHAPTER XI

## PERCEPTION (*Continued*)

### Perception of Movement

**Visual Perception of Movement.** — How the eye appreciates movement is a problem closely related to the perception of space; in many ways it is intermediate between the perception of space and of time. Two forms of movement must be distinguished: one in which the movement can be actually seen; and a second in which movements are so slow that one infers that the object has moved from the fact that its position changes between two observations. The movement of a meteor belongs in the first class; that of the sun in the second. The slowest rate that can be really seen is one angular minute per second. Movements may also be too fast to be seen directly. An electric spark moving more than 15″ in a thousandth of a second cannot be seen to move. Nothing more is seen than the path. Three different theories of how we perceive the intermediate rate may be mentioned. The first holds that the eye follows the moving object, and that appreciation of the movement of the eye gives also a knowledge of the movement of the object. This theory is very direct, but depends for its acceptance upon proof of ability to appreciate the movement of the eye muscles. Recently, various bits of evidence indicate that movements of the eye muscles are much less accurately known than has been sometimes assumed. In the first place, there is little accuracy in estimating the movement of an object when it

stands alone in the field of vision. A faint light moving in the dark may seem to move much more slowly than it really does; and, on the contrary, a stationary light in the dark may seem to be moving. If two faint lights are attached to the ends of a rod revolving about a point near its middle, the appreciation of the movements is uncertain. Either light may seem to move, while the other is stationary, or the motion may be divided between them in any proportion. When only two lights are in the field, one sees the relative but not the absolute motion. When stationary objects are in the field, it seems that the movement of objects is determined by their relation to the fixed objects in the field of view, rather than by following the object with the eye, and appreciating the movement through the contraction of the muscles.

**The After-image Theory.** — Stern, among many other writers, has suggested a second theory, — that movements are appreciated through the after-images which the moving object leaves upon the retina. Watch any object in fairly rapid motion and you will notice that it leaves a trail of after-images as it moves and that its course can be distinctly made out for a few moments by means of this trail. The motion of the moving picture is due, on this theory, to the fact that the separate pictures of the object also leave a line of after-images and that these are interpreted to mean motion. The motion seems continuous if the separate images succeed each other with an interval of no more than fifteen thousandths of a second, a rate much higher than that ordinarily used in exhibitions, fifteen to twenty per second. This theory may be applied to explain the differences between the three kinds of motion: movements too slow to be seen must leave no after-image that can be noticed; while in movements too fast to be

seen, no distinction can be made between the after-image and the primary stimulation, the whole course is of approximately the same intensity; only when the after-images actually outline the path of the moving object on the retinas, in motion of moderate rate, do we actually see movement. The trail of after-images also affords a means of determining the course of the motion. It is more intense near the stimulus and becomes gradually fainter the greater the distance from the stimulus. After-images, then, are interpreted as motion, and the direction of the motion is assumed to be from faint to vivid images.

**After-images of Movement.** — That motion itself has an after-image is an important fact for the theories of movement, and its study has contributed much to the explanation of movement in general. If one look for several seconds at any moving surface, the paper on a kymograph, a stream, or at a revolving spiral, and then look away at a stationary surface, there will seem to be a movement in the opposite direction. Two explanations of this phenomenon have been offered; that it is due to the reversal of the after-image, and that it is due to an actual displacement of retinal elements by the motion, followed by their return to the original position when the movement ceases. Visual after-images change from positive to negative shortly after the stimulus is removed, as will be remembered from an earlier chapter. If in the original motion the after-images near the object are dark, and the more remote are brighter, in the negative after-image the dark portion becomes bright, and so the more remote parts will appear brighter. The negative after-image of brightness accounts for the apparent reversal of the movement.

**The Theory of Retinal Streaming.** — That the perception of movement and the reversal of direction in the

after-image are due to actual movement of elements in the retina has been asserted for some time and has been strongly supported recently by Ferree and Hunter. This is our third theory of the perception of movement. The evidence in its favor is the great vividness and persistence of the sensory processes, particularly in the after-image of movement. These observers assert that when the after-image of motion is well developed, there seems to be a veil of objects streaming over any surface looked at, and that it would be impossible for after-images or any of the other factors suggested to persist long enough or be sufficiently realistic to account for the effect noticed. On the other hand, they admit that what we know of the retinal structure gives no evidence in favor of an actual movement of its elements. Altogether the after-image theory seems more plausible. After-images are known to exist and must aid in the perception of motion. The only question is whether they account for all of the observed phenomena. We may at least accept the after-image theory as the most probable at present for the explanation of all perception of movement.

Considering the problem of how we see movement at all to be settled, it is still necessary to consider how we distinguish between possible interpretations in actual movements. Many of the phenomena may be the result of several different conditions in the outer world. Either the eye or the field of vision may be in motion when many objects are leaving after-images. We may distinguish three conditions of motion, if we consider only the movements of objects and of the eyes. The eye may be stationary and one object in motion; the eye may be in motion, following one object, perhaps, while the rest of the field is stationary; or, finally, the eye may be following one object while other

objects are moving in different directions or at different rates.

The first case has been discussed above. In the second case, one would have a clear image of the object that was pursued by the eye, while all other objects would be seen in blurred images or would be leaving after-images. Here we must explain how we know that the eye is moving. This might be, either through the sensations from the eye muscles, or by the after-images, or other signs of movement developed on the retina by stationary objects. The clear image of the object in flight would show that it was being properly followed, while the after-images of all other objects serve as an indication of the movement of the eye.

Still more complicated, but nevertheless capable of explanation along the same lines, is the problem offered when the object and eye are in motion in different directions or at different rates. Here the total estimate is based on a comparison of the movement of the eye with the displacement of the image. In each of these cases much depends upon the estimate of the probability of movement. Even when it is a question whether the motion is of the external object or of the observer, interpretation is important. If one stands on a bridge over a rapidly running stream, it is quite easy to ascribe the motion to the bridge. The probabilities in the light of frequency of occurrence are that a small object like a bridge will be in motion rather than the larger river. Similarly, when you are on one of two trains standing in a station, and one starts, motion is ascribed to one or the other in accordance with your expectations. Not merely the sensory elements that give the perception of motion must be taken into account, but also the estimation through early experience of the probability that the object is or is not likely to move.

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## RHYTHM

Most series of excitations which repeat themselves at short intervals tend to fall into rhythm. Rhythm needs no description, and one could not be given if demanded. Two factors may be distinguished in rhythm, the grouping of the single elements into units, and the accenting or emphasizing of one or more of the units. Auditory and kinæsthetic impressions show rhythm most easily; tactual and visual, not so markedly. The accentuation in rhythm may be produced in a number of different ways all of which give the same effect. It can be given subjectively as well as objectively. If one listen to the ticking of a clock or the beats of a metronome, it will be noticed that they tend to form units, and that the character of the unit, the sound that is accented, will vary from time to time, and within limits, can be changed at will. Objectively, it is possible to emphasize one unit in the measure, either by increasing the intensity of the note to be accented, or by increasing the length of the note. This is evidenced by a comparison of ancient with modern verse. While the former produced its rhythmic effect by lengthening the syllable, English poetry obtains the same effect by increasing the intensity of the syllable. A similar difference in the way of producing effects can be seen in music of the organ and of the piano. On the organ the intensity is constant, rhythm is

obtained by increasing the duration of a tone, while on the piano, accent is given by increasing the intensity of the note. The rhythm is the same in both cases. In fact, men who have played the organ for years often do not notice either the difference in the effect or in the way in which it is produced. Not only may accent be given by changing the character of the note, but also by changing the intervals between the notes. In a measure of three notes of the same intensity and duration, if the first interval be increased, the first note will be accented; if the second interval be increased, the last note will be accented.

The way in which groups are formed in regularly recurrent sensations may also be reduced to certain laws. The more rapid the rate of succession, the greater the number that may be brought into a single unit. In very rapid beats of the metronome, two hundred per minute or so, it is possible to combine as many as eight beats in a single unit. The size of the unit may be varied at will within limits. When they are sixty or less per minute, it is with difficulty that two may be grouped. In general, Woodrow found that in a series of tones separated by equal intervals in which every other note or every third was more intense, the group would begin with the more intense tone. When intensities were equal but alternate notes were longer, the longer note would start the measure. The grouping and the accent depend upon both objective and subjective factors.

**The Theories of Rhythm.** — Two theories to explain these various facts of rhythm are at present current. One is that rhythm has a motor origin, that the impulse to beat time is universal, and that any external series that will call out this tendency produces the rhythm. Genetically, it is argued that rhythmic movements are inseparable from bodily activity, that the movements in physical labor came to take

on a rhythmic form, and this may have been transformed into the dance, which in primitive races is frequently derived from the daily work, and that it then was introduced into music and reached its present degree of complexity.

The other theory, based on attention, develops from the fact that most of the factors which induce accentuation also give rise to attention. Both intensity and length of stimulus were found among the objective conditions of attention. More striking is the evidence from the effects of the preceding and succeeding interval. A period of expectation is an important factor in arousing attention. Where a note in the rhythmic group has been preceded by an interval, expectation increases regularly during the preliminary wait; and when the stimulus finally makes its appearance, it is more fully attended to and seems more intense than impressions that have been preceded by the shorter interval. Less obvious is the explanation of the effect when a longer interval succeeds the stimulus. This seems to offer opportunity for full attention to the effect of the stimulus after it has stopped, and this is supposed also to increase its apparent intensity. It seems probable, from observation and particularly from the fact that an interval affects the accent of the note that preceded, that the appreciation of the rhythmic unit takes place at the end of the measure. The unit is heard as a whole at the moment it is completed rather than bit by bit as each impression comes to consciousness. The attention theory, then, would hold that rhythm is induced by any circumstance that makes some one or more elements in the series of tones occupy a more important place in consciousness than the others, and that the whole group becomes a unit for attention.

While the attention theory has some advantages in explaining why the emphasis comes as it does, it seems

probable that a considerable portion of the sensory content of the rhythm is supplied by the motor contractions which may come as a result of the subjective accentuation. A good case can be made for either theory, and they are not at all contradictory or out of harmony one with the other.

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## Perception of Time

**Problems Concerning Time.** — Time offers many of the same problems as space. It, too, is a universal characteristic of all our experience, and there has been the same discussion as to whether it has real existence or is merely subjective. As with space, we may ask how short a time can be noticed, and how we appreciate longer intervals. The traditional question, how short a time may be experienced, receives a different answer for each of the senses and combinations of senses. It is much shorter for hearing (.002) than for sight (.044) and may rise to 0.16 second when one stimulus is given by sight, the other by the ear. When one turns to a study of the longer times, it is found that the estimation of time and even our awareness of the passage of time vary greatly with the duration of the intervals involved. If one is asked to listen to times of different length, certain times are at once pronounced very short, too short to be perceived with comfort, others as too long to be easily appreciated. Times under $550\sigma$ ($\sigma$ means thousandths of a second) seem too short, are hurried, and not adequately comprehended. On the other hand, times over about $1800\sigma$ seem very long, and it is with difficulty that they can be brought within the span of comprehension.

At about four seconds, it is no longer possible to bring the events within a single compass; one reaches the limit of a single span of time so far as it can be experienced. It should be noted that this is also approximately the length of the primary memory. Within this period events may be held in a single span of memory, and the memory image can be used with the same care and certainty as a sensation. It is by virtue of this fact that it is said to constitute the immediately experienced present.

**The Different Ways of Perceiving Time.** — The point of division between the hurried and the comfortable time is of interest for another reason. It is found that if one attempts to compare times under 0.6–0.75 second, there is always a tendency to overestimate the first; while similar comparisons of times, greater than this indifference time, lead to the underestimation of the first. This time approximately coincides with the point of division between the times felt as very short and those which seem of moderate duration, and furnishes additional evidence that there is a real difference in the means of estimating times above and below. Some light may be thrown upon the conditions of the perception of time by a study of the factors that influence the comparison of intervals. First, anything that influences expectation is important. Thus, if sounds are separated by equal intervals and every alternate note is more intense, the interval that precedes the more intense sound will seem to be lengthened. This has been explained as due to the surprise induced by the strong tone, which increases the strain ascribed to the preceding interval.

The filling of an interval also influences its appreciation. With short times it is found that filled time seems longer than empty. If the time be longer, and one be permitted to read during one period and to do nothing during the other,

the time spent reading seems shorter than the empty. The probable explanation of the latter difference is to be found in the fact that the empty time is really filled by noticing strains and other internal sensations, while, during the time occupied in reading, these strains are not present. One forgets one's self and the passage of time in the interesting event. For longer times the filling seems to have a markedly different effect according as the time is regarded as it is being lived through, or as it is viewed in retrospect. While passing, time in which one is occupied fully and during which much of importance is happening seems short, but when viewed in retrospect it seems long. Empty time, on the other hand, seems long in the passing but short in retrospect. During convalescence from a long illness the days drag interminably, but later the period seems inappreciable.

**Theories of Time Perception.** — Attempts at a theory must take all of these facts into consideration and we must distinguish three ways of appreciating time. The first applies to the very short intervals, those under 600–700$\sigma$, below the indifference period. These, it has been suggested, are appreciated in terms of rhythm, since under that limit stimuli may be easily grouped into rhythmic wholes. The intervals are too short to be appreciated for themselves, they cannot be attended to, and so do not reach their full development. The second is effective for times between 600 or 700 $\sigma$ and two to four seconds; this is real time. It is apparently appreciated in terms of internal experiences, expectation processes, and other more definitely kinæsthetic sensations. The length of the time is estimated in terms of the intensity of the strains. Short times give strains no chance to become strong, but their strength grows with the longer times. Strains of the muscles that accompany attention, strains of expectation, even strains that come with

respiration or with holding the breath, have been asserted to form the basis of the appreciation of the passage of time. The influence of the strength of the limiting stimuli would suggest the importance of the strains of attention in the estimation of time, as would the effect of the content of time. When the interval is empty, attention is more fully attracted to the passage of time, the strains are more pronounced, and the time seems longer. In the same way with longer intervals when there is nothing to do, the strains of expectation occupy consciousness and time seems long, while, when one is busy, attention is otherwise occupied and there is constant change, constant relaxation, the strains never rise to great intensities, and in consequence one is not impressed with the fact that time is passing.

Times longer than from two to four seconds are apparently not directly experienced in the passing, but are only experienced as past. They fall outside of the present, are constituted for the most part by memories of past events revived in the present. They are estimated in terms of events that have happened in them, in terms of the occurrences which fill them. In this they differ altogether from the shorter intervals that may be directly appreciated, and in consequence show the reverse illusions. Thus, times that are filled with interesting events seem long when they are looked back upon, although they seem short in passing; while times in which nothing happens seem short in retrospect, although extremely long in their passage. It is this that explains the seeming decrease in the length of the days and weeks with advancing years. When one is young, all is interesting from its newness, and is always attended to; as time goes on, nearly everything becomes familiar, and receives less and less attention, and so less and less is remembered in retrospect. In general, times depend upon an

appreciation of that which fills them. Very short times are apparently known from rhythm, longer times from the physiological processes, contractions and what not, that give the feeling of expectation and strain; while intervals longer than from two to four seconds. are appreciated from the events that happen in them.

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## THE GENERAL LAWS OF PERCEPTION

While space and time may be treated separately, since practically all perceptions imply them and they are considered to have an existence independent of the objects found in them, certain laws of perception can be illustrated only by a study of the way in which separate objects are perceived. Speaking generally, it may be said that a percept is practically never merely a mass of bare sensations. The sensations at most provide a suggestion which is developed in consciousness to make the object as we appreciate it. In optical illusions, certain elements are added, certain others are subtracted from the immediate group of sensations, before we have the final percept. One is not aware of either the additions or the subtractions, much less of the sensations as immediately given before the modifications are made. This same process may be demonstrated to take place in practically every perception as we appreciate the nature of the real object. We are aware only of the final process, the object, but we can be sure from experi-

mental data that this is not merely a mass of sensations, but is the result of a complicated series of mental operations.

**Reading.** — One of the best means of studying the various laws of perception is furnished by reading. Here the material is relatively simple and we have fairly full experimental evidence concerning the different phases of the process. First it may be asserted that the word, not the letter, is the unit for reading This is demonstrated by the experiment on the distribution of attention. As was said in connection with attention, five or six letters is the maximum that can be distinguished on short exposure, but, when combined into words, twenty-five to thirty letters may be read at a single exposure of $\frac{1}{100}$ second. Evidently something must be added to what is seen, or the word must be read as a whole rather than by single letters. There is evidence that both processes go on in some degree. Zeitler and the writer found that the reader was influenced by the general form of the word as determined by the relative positions of high and low letters, the length of the letters, etc. This is indicated again in print by the fact that one is much more likely to make mistakes and to have greater difficulty in making out the words if the upper parts of the words are cut off than if the lower be covered.

On the other hand, the proofreader's illusion indicates that there is a constant tendency to supply letters or parts of letters from memory, to add centrally to peripherally aroused sensations. The writer found that if words were printed with letters omitted, with blurred letters, or with substitutions, and shown for a fifth of a second or less, they were read in a large proportion of the cases as if perfect. The readers would occasionally give reports of the character of the letters, supplied or transformed, which indicated that they belonged in the class of the centrally

aroused sensations. The letters that were supplied or replaced were faint, had a peculiar color, or seemed to be less permanent than the others. The likelihood of reading the misprinted word as if it were correctly printed was much increased if a word associated with the word to be shown was called before the exposure. This gave the right attitude or setting for seeing the word intended. That supplementing is a factor even in the simplest reading is shown by the large number of misprints that are overlooked, some even by the most accurate proofreaders. The supplements in this case are not so permanent as are those in optical illusions. The latter persist for a considerable time in spite of all that one can do, and can be destroyed only by a long period of practice, but the proofreader's illusion vanishes when first one looks to make sure that a mistake has not been made.

**Reading Pauses.** — One might deny that the conditions of ordinary reading, in which all the time that may be desired is given for looking, are similar to those in which the exposure is limited to a period too short to permit eye movements or wandering of attention. Recent studies of the mechanism of reading show, however, that the conditions are not markedly different. In the first place it has been found that, while reading, the eyes do not move steadily along the line with full time for the observation of all details, but make a few brief pauses. Photographs of the eyes as they move along the line show that they stop only from three to six times in a line of ordinary length, and then for but a very short time, approximately a fifth of a second. The number of stops varies greatly with the character of the material to be read. In reading a novel or similar light literature, the number is a minimum, and rises to a maximum with difficult material, in proofreading,

and for children who are learning to read. One really takes a series of snap shots of a line and pieces it together from them, rather than reading continuously. There can be apparently no reading while the eyes are in motion; they move so rapidly that nothing but a blur of after-images is left on the retina, and as this gives no knowledge, we have learned to pay no attention to it.

**Reading a Process of Supplementation.** — All this leads to the conclusion that ordinary reading is a process of inferring unconsciously from the form of the words and a few letters what the word actually is. This process of inference is really nothing more than associating with the letters seen certain other letters frequently found with them, or of associating whole words with what little of the word is seen. Like all associations, these are under the control of the mental attitude, largely determined by the context and the knowledge that the reader can bring to the reading. The influence of the context can be seen in the different pronunciation and interpretation of a word composed of the same letters in different contexts. 'Lead' has one pronunciation when the subject of the sentence, another when it is the predicate, and we do not think of the one when the other is meant. The meaning is determined by the context, and what has gone before. Still more striking is the difference in pronunciation and interpretation that attaches to the same group of letters in different languages. *Man* has an entirely different sound and meaning in English and in German, and many other illustrations could be found. Suffice it to say that the sounds or ideas that are aroused depend very definitely upon the context.

In reading it is evident, too, that the process of perceiving or of interpreting is not complete when the word as such has been seen. The process of translation into

ideas follows. Sometimes one sees the words and follows them along with the sound of the spoken word, and thus has the ideas produced indirectly. Experiments show that to depend upon translation through internal speech is of no advantage and makes reading unnecessarily slow. More frequent in the adult is the immediate translation of the words as seen into images or ideas of some sort. As one reads in the most complete way, pictures or more abstract ideas accompany the reading. The clearer the style, the more immediately do the ideas follow upon the perception of the words and the less prominent are the words, until with a maximum of clearness the words are largely neglected and the meaning alone comes to consciousness. This meaning may take the form of picturing the scenes described, of merely appreciating the abstract meaning, or of something intermediate. In any case, the outlines of black and white that constitute the words start the association processes that lead to the ideas, and these associates are controlled by the wider setting and wider knowledge of the individual at the moment. The process is much like that in ordinary recall except that the stimuli are constantly received from the words. The revival of the earlier experiences is controlled by the laws of association and by the context in a degree that practically amounts in many cases to new construction.

**Understanding Spoken Language.** — A similar process occurs in listening to another's speech. One does not appreciate how small is the proportion of a conversation that is heard distinctly until one attempts to follow a foreign language. Then it is seen that what must be perfectly clear to a native as a vehicle for ideas is really only a series of grunts and hisses with an occasional word clearly enunciated. Suggested by these, the words or the ideas are

supplied through association. Bagley has shown that there is a process of filling out the imperfections of sounds similar to the interpretation of letters in reading. The laws of supplementing are practically the same in the two cases. Something is given by the ear, this suggests words as one would speak them one's self or as they would look on the printed page. This is all that is really appreciated, and even when one listens for the words, the imperfections are not noticed. When one hears a strange accent, the different deviations from the sounds one is accustomed to are overlooked, the man is assigned to his region of the country, and then no more attention is paid to the speech characteristics, unless one be interested in phonetics or have some other purpose in hearing the sounds, and in such cases the sense of what is being said is very likely to be lost. Artificial languages gradually take on the same character. The separate elements become united into word units, and then acquire meaning, as do words themselves. This comes out particularly clearly in learning the telegraphic language. There at first the sounds are heard as small groups and put together painstakingly and slowly into letters, but gradually words are heard as wholes and the meaning is suggested by a few words and omissions are filled in as in ordinary speech. Supplementing follows the same laws as in reading or listening.

**Résumé of the General Laws of Perception.** — If one may extend and generalize the laws of perception in reading and listening, it may be said that perception is primarily a process of arousing old experiences through association. These associations are controlled by both the subjective and the objective factors. Some few sensations always serve as the incentive to the perception process, but they serve as the incentive only. By them associations are

aroused and, in that arousal all the experiences that have had any bearing on the process contribute their share. Some of the associations are determined through mere frequency of appearance with the original stimulus; others depend upon the attitude in which one is at the moment of looking or listening, and upon the inherent probabilities of the situation. That one is not more often misled is due to the fact that objective situations repeat themselves so frequently, quite as frequently as do ideas. It is safe on the whole to assume that what we take as the sign of an old situation really accompanies that situation, for in the vast majority of cases the remainder of the elements are actually present. In practice it would take more trouble to stop to investigate than to take the chance and be wrong the few times that the new does not correspond to the old. It is striking, however, that in this case alone one does not distinguish between real sensations and the recalled images. Centrally and peripherally aroused sensations are combined in almost all perceptions, but one never can tell where the sensations stop and mental supplements begin. One seems as real as the other.

**The Influence of the Type in Perception.** — In conclusion we may again emphasize the importance of *type* or *concept* in perception. This is a factor common to both perception and reasoning, — this is the tendency to replace a particular phase or aspect of an object by what has proved to be its more general or universal form. Usually one sees things as the previous experience convinces one they must be, rather than as they appear at the particular moment. Thus, one usually does not notice shadows as shadows, although they may aid much in the interpretation of the form of the surface on which they fall. Similarly, one does not notice how indistinct are objects in the

field of vision a little distance from the fixation point. What is seen is at once translated into an object of perfect form with full detail and distinctness, and all else serves as a mere background. Still more striking is the correction of the size of various objects. The standard size varies for the different objects. No matter how small or how large the image may be under a given set of circumstances, it is increased or decreased to a standard size. The image itself is never seen, the fact that it has been changed in its size also is not noticed; the corrected standardized impression at once replaces the retinal image. This standard we regard as the real object.

Similar tendencies to replace mere sensation groups by concepts or by standardized objects may be seen anywhere. The neglect of after-images, of contrast colors, the overlooking of imperfections in the media of the eye that can be seen clearly when one looks for them in a lamp flame, overlooking the retinal blood vessels in the visual field, — all of these omissions are quite as apparent as is the addition of qualities or characteristics not given in sensation. Equally striking are the changes in the forms of objects seen in perspective. As any article of furniture is looked at, the square corners are either increased to oblique angles or reduced to acute angles, according to the side from which one looks. A hundred students looking from different directions at the lecturer's reading desk will each receive a different impression, different in shape as well as in size, but the object is the same for all. The perception is changed in being seen, or a standard object is made to replace the various images, so that the final result is the same for each observer. This process of replacing the crude image by a standard object, an object that has been developed by all of the individual's experiences, that has been

gradually corrected by being seen under different conditions, by being handled, and even by making similar objects or seeing them made, is practically universal. It is the developed standard object that always comes to consciousness, just as it is the corrected standard space that is always used as the basis of reference. To anticipate the discussion of a later problem, it may be said that we perceive concepts rather than sensations. As concepts that have developed in this way, we have not merely objects, but space and time and ssmilar abstractions which are in part components of the objects, in part to be regarded as independent.

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## CHAPTER XII

## MEMORY

MEMORY is a topic that bulks very large in the discussions of daily life. In the complete form it may be defined as the recurrence of a group of experiences with knowledge of the time and the place in which they were experienced before. Memory is related to centrally aroused sensation in very much the same way that perception is related to sensation. It is a group of centrally excited sensations accepted as representing some earlier seen object or previous event, as perception represents an object actually present.

While the fundamentals of memory have been discussed, there is much of more particular application that remains to be considered — questions as to how the association processes may be used to the best advantage in the accumulation and application of knowledge. We may conveniently divide memory into four part processes, — learning, retention, recall, and recognition. Learning is no more than the formation of association; retention is the persistence of those associations; recall is the rearousal of old experience; and recognition, the process of assigning the events to the time of their first appearance. Although association has been treated in general, we must consider here a large number of special rules and laws developed through experiment that throw new light on the nature and use of memory. To have the associations is not identical with being able to use them. We shall weave together the results obtained from experiments on the first

three processes, before we consider recognition which involves certain relatively new principles.

We may distinguish in the discussion of memory between the retention and recall of concrete objects and the recall of words or symbols. The process is different in the two cases because the symbols must be remembered directly, while the concrete objects are sometimes remembered directly and sometimes translated into symbols which represent them. The differences are sufficient to make it desirable to treat the operations separately. The first we may call observational, the second, verbal memory.

## Memory of Objects and Events

**Observational Memory.** — Observational memory derives its great practical importance from the fact that the evidence of the witness on the stand must depend for its accuracy upon this type. It is, of course, also the method that we use in describing the events of the day in conversation. Much, too, of the work of the observational sciences that is not recorded at once in notes depends upon the accuracy of this form of memory. We may say that the accuracy of recall depends: first, upon the way the material is seen at the time of the observation; secondly, upon the time that elapses between observation and report; and thirdly, upon the circumstances effective at the time of recall. What is seen depends upon the way the observer attends and upon the way he translates what he sees into words for retention and recall. Most individuals will notice objects, their form, position, and number first, and with an accuracy diminishing in that order. Colors are seldom noticed. Children are much more inaccurate than adults in all except possibly the observation of colors. Special practice in observation of any kind will greatly in-

crease the accuracy of observation. Practice is of some general value in calling attention to what is likely to be overlooked, and enabling the observer to attend especially to that. Accuracy is increased, too, by describing in words what is seen, and remembering the words rather than trusting to the images alone. Thus, if one will count the windows in a building as one looks, one will remember the number, but if one attempts to count them in the memory picture, the result is very likely to be wrong.

**Effect of Lapse of Time on Accuracy.** — The effect of time is always in evidence. Dallenbach found that forgetting took place rapidly at first and then more slowly, a law that holds for forgetting all types of material. Thus immediately after exposure, ten per cent errors were made; after five days this had increased to fourteen per cent; after fifteen days, to eighteen; and after forty-five days to twenty-two. The material used consisted of pictures, and the percentages were obtained by counting the number of objects in the picture and determining what per cent of them was recalled. It will be noticed that there was the same increase in the number of errors between one day and five as between five and fifteen, and fifteen and forty-five.

Most errors of report that develop at the moment of recall are due to the suggestion of objects that were not actually seen. Any idea that presents itself is certain to suggest others, and this suggestion may lead the observer to think that it was actually present. This is an extension of the tendency for what is present to suggest at the moment of observation other things that are not really seen. Something is definitely recalled, and this suggests something else that usually goes with it. This arousal of the idea may be accepted as constituting evidence that the object was really seen. Very striking is the influence of questions

in increasing the number of errors. If the individual is told to tell all that he saw, he will make a report that is approximately ninety per cent correct. If he is questioned as straightforwardly as possible about the objects in the picture, the errors will increase so that he may have only seventy per cent correct. The advantage of questioning, which makes it essential that a witness be questioned in a court, is that many things he might report on will not suggest themselves without questions. Experiments show that the spontaneous report covers only twenty-five to forty per cent of the total number of objects present, while questions will increase this range to fifty or sixty-five per cent. What is lost in accuracy is gained in range. If leading questions are asked, particularly if they assume a wrong answer, the percentage of errors is increased much more. If one asks the color of the dog in the background, when no dog was present, about half of the individuals, even of superior intelligence, will give some color.

## Rote Memory

**Experimental Methods.** — Careful experiments on memory were first made by Ebbinghaus in the eighties of the last century. To avoid the variation in degree of familiarity and interest that might attach to words or any other material that has meaning, nonsense syllables were selected as the material to be learned. These were built up of consonants and vowels, two consonants with a vowel between. All combinations were excluded that chanced to make sense. Series were selected by lot from the mass of syllables. Ebbinghaus wrote his series upon cards and then learned them by shuffling the cards. Most later workers have arranged the syllables upon some sort of revolving drum that exposes them at regular intervals and for defi-

nite times. They are said through regularly as they are exposed, until they can be repeated once or twice without mistake. Ebbinghaus measured the amount of effort in learning by the time required, but most later writers have chosen the number of repetitions as the measure. Two methods have been used to test the accuracy of the learning or the amount of retention. The first, known as the method of relearning, was used by Ebbinghaus. It consisted in relearning the syllables, and assumed that the difference between the time required for learning and for relearning was a measure of the amount retained. This also measured the value of the method of learning used. In a second method, the method of paired associates developed by Müller and Schumann and extensively used since, the syllables are learned in pairs and the amount retained is measured by showing the first member of each pair and asking the observer to supply the second. The percentage of correct answers indicates the amount retained. In many experiments, the time required for speaking the second syllable is measured. This serves as an indication of the strength of the association for individual pairs. The shorter the interval required, the stronger is the association. Each of these methods has given valuable results. They frequently supplement each other. The first measures primarily the effective and latent memory of the whole; while the second permits a study of the effective connections between members of the pairs. One measures potential liability to recall; the other, the actual recall.

## THE LAWS OF LEARNING

**Effect of Individual Repetitions.** — One of the first preliminaries to the application of the method was to determine the accuracy of the method itself. This involved first

a determination of the effects produced by each repetition when a number of repetitions of the same series are made. Ebbinghaus tested this by repeating a series of syllables eight times and then finding the time required to relearn after twenty-four hours. He then repeated another series sixteen times and again relearned after the same interval. These experiments were repeated up to sixty-four repetitions of a series. Within these limits the amount retained

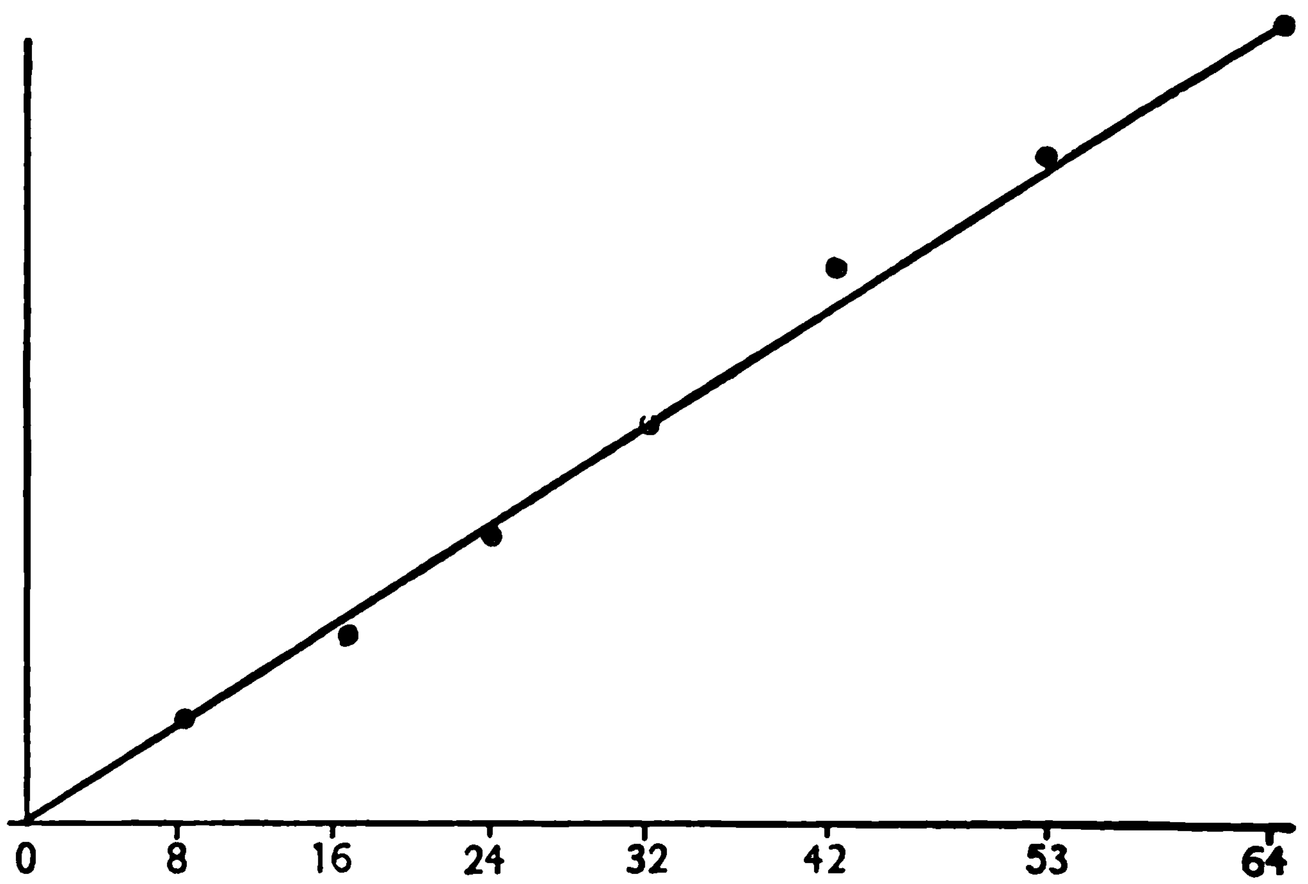


FIG. 91.—Shows the increase in amount retained after twenty-four hours with the number of repetitions. The number of repetitions is plotted on the horizontal, the saving in seconds on the vertical axis.

after twenty-four hours was directly proportional to the number of original repetitions. The last repetitions were no less effective than the first as measured by the amount retained. The diagram shows that the results, when plotted, lie almost in a straight line. Each repetition resulted in a saving of about twelve seconds in the time required for relearning. This experiment also brings out the fact that learning is never absolutely complete or perfect. Perfect learning at the moment will show defects in a few

hours or days, and the duration and accuracy of retention may be increased by repetitions much beyond the number required for the first perfect repetition. Each repetition will have the same effect as any other in the recall of the next day or of the next week.

**Relation between Length of Series and Number of Repetitions.** — One of the more striking facts in connection with learning is the great increase in the number of repetitions required for the longer series as compared with the shorter. It is found that an adult can remember from 6 to 8 syllables or 11 to 13 numbers with a single repetition, while Ebbinghaus found that it took 13 repetitions to learn a series of 10 syllables, 16.6 for 12, 30 for 16, 44 for 24, 55 for 36. As the number of syllables in a series increases, the number of repetitions required for learning it increases much more rapidly than in proportion to the increase in the number of syllables. The most striking increase is seen when the series is just longer than can be learned with one repetition. The number of syllables that may be learned at a single reading to be repeated immediately has been called the memory span, or primary memory. This varies very markedly with age, with training, and with the individual. It may be much increased by training at any age. According to Meumann, children from seven to nine can usually retain no more than two or three nonsense syllables, while the practised adult retains seven or eight.

**Effects of Grouping.** — Learning a series not only forms associations between the contiguous syllables of the series, but knits the whole group together by associations formed between all of the syllables, however widely they may be separated. Ebbinghaus demonstrated this by learning certain series and then making up new series that should

consist in part of the syllables of the primary ones. Thus, he would select syllables that had been separated by one syllable; and he found that the new series could be learned more easily than new syllables. He repeated the experiment, using syllables that had been separated by two, three, etc., syllables, up to those that had been separated in the original learning by as many as eight. He found in each case that a saving could be shown as compared with entirely new series. The results prove that associations are formed between the remote as well as the contiguous elements in a series. He also showed that associations are formed in both directions, backward as well as forward. Relearning a series backward saves about one-third of the time which is saved in relearning forward. It has also been shown that some connection is formed between the syllable and its position in the series. Syllables that are relearned in the same absolute position in a series are relearned more easily than when they take a new position. If the syllable is the third or the seventh in the series and is kept in third or seventh place, relearning is easier than if it is shifted to second or fifth place in the new series. All of these bonds of connection aid in making the series a unit.

**Effects of Rhythm.** — Anything that serves to unite the syllables into minor units is of advantage in aiding learning. One of the means employed most frequently is rhythm. In repeating a series, the syllables are practically always combined in rhythmic units and given an accent. Learning in the natural rhythm is much easier than in a forced rhythm or without rhythm. The natural rhythm varies with the individual and probably also with the race, but whatever the rhythm used, some benefit is derived from it. The rhythmic unit also serves as a subordinate group within which associations are much stronger than between

contiguous syllables of different groups. Müller demonstrated this by first learning series in trochaic rhythm and then forming from the syllables two sets of new syllables. In one of these, the syllables were relearned in the same measures as in the original series; in the others, the syllables were contiguous but had belonged to different measures. The former showed a saving on relearning equivalent to five repetitions; the latter, no appreciable saving. This strong association within the group holds, not merely for the grouping in rhythmic units, but for any grouping. In learning nonsense syllables, practically no association is formed between the first syllable of one series and the last of the preceding. In common life little connection is established between conversations on different subjects with different persons, even if one immediately succeeds the other. On the other hand, where material to be remembered is broken up into smaller groups of a larger series, members of these groups are more closely associated for themselves, and learning the groups aids in learning the total series. This formation of subordinate groups is of great practical importance, and we shall have occasion to refer to it in connection with the development of meaning.

**Learning by Whole and Part.** — One of the most important practical laws for learning is that it is much easier to learn any selection if it is read as a whole instead of being learned by parts. This applies to nonsense material under strict experimental conditions, and also to ordinary sense material, poems, etc. An investigation of this point was first undertaken by Miss Steffens under the direction of Professor Müller. It consisted in comparing the time required for poems when learned as most people incline to learn them, a line or a couplet at a time, with the time required when they are read through from beginning to end

each time. The results indicate that, in practically every case, learning as a whole is more economical than learning in parts. The saving amounted to about ten per cent in Miss Steffens' experiments and held for children as well as for adults. Later investigations by Meumann showed that two stanzas required thirty-three repetitions by the part method, and only fourteen for the whole procedure. It should be said that unless some method of keeping the repetitions at a uniform rate be employed, the learner tends to lose interest and to repeat more slowly than he will if he is permitted to learn by parts. In some experiments this loss in rate almost offset the advantage gained from the need for fewer repetitions. With much practice, this loss may be overcome. The law has been demonstrated repeatedly. Not only does learning require fewer repetitions, but the material learned as a whole is much better retained than material learned in parts. There is also a fairly wide limit of application, as the whole method was found more economical by Pyle for selections that required as much as fifty minutes to read through.

The reasons for the greater efficiency are threefold:

1. They save much of the time ordinarily wasted in needless repetitions. In the part method, the first part of the selection is repeated more times than necessary through going back to connect the later learned with the earlier. There are several times as many repetitions of the first as of the later.

2. Needless associations are made each time the reader goes back from the end of a line to its beginning. These take time and also may interfere with the formation of the correct associates.

3. As was said above, the connection of a word with its position in the selection is of some advantage in

learning, and the whole method always retains the absolute position of each word.

Meumann and his pupils have shown that certain intermediate methods may improve on the strict method. Thus, it is frequently an advantage, after a number of repetitions of the whole, to repeat several times the parts of the selection that offer special difficulties, and to learn them without making unnecessary repetitions of the easier portions. One can also obtain some of the advantages of the part method by making pauses at certain places, then in each case going on from that place after a few seconds. These pauses seem to attract particular attention to the words preceding and succeeding them, without the disadvantage of forming useless connections. In general, it is recommended that one read through the selection to be learned a few times as a whole; then, as fatigue comes on, introduce the pauses and, when it becomes evident that certain parts are offering special difficulties, make an extra number of repetitions of those parts until they are learned, then add a few repetitions of the whole to weld all together.

**Distributed Repetitions More Effective.** — Another law that is equally well established, quite as important in practice, and even more interesting, is the so-called law of divided repetitions. Briefly, this is that the more the repetitions are distributed over different days, the fewer the repetitions required and the more thoroughly the material is mastered. This conclusion was first carefully investigated by Jost. He tried learning nonsense syllables with twenty-four repetitions at one time, then similar series with eight repetitions per day for three days, then four for six days, and finally two a day for twelve days. It was found when they were tested by the method of paired associates twenty-four hours after the last repetition, that the fewer the repe-

titions each day, the greater was the amount retained. Ebbinghaus had earlier compared greater numbers of repetitions. On one occasion he read a series of twelve syllables 68 times and found that twenty-four hours later he needed seven repetitions to relearn. Then he repeated another of the same length, $17\frac{1}{2}$, 12, and $8\frac{1}{2}$ times, a total of 38, and found but five repetitions were needed for relearning twenty-four hours later. Still later Miss Perkins[1] continued the extension of distributions, comparing accumulated repetitions of eight a day for two days, with four and two and one repetition per day, every other day, every third, and every fourth day. The results were tested after fourteen days and proved even more striking than those of the earlier tests which were made after twenty-four hours. Eight repetitions a day for two days gave only from 9 to 17 per cent correct responses, and the larger number was obtained when three days were permitted to elapse between each series of eight repetitions. Four readings a day gave from 25 to 41 per cent, with larger values for the wider distribution of repetitions; two a day gave from 45 to 78 per cent, while a single repetition every day gave 79 per cent; a single repetition every other day, 72 per cent; every third day, 82 per cent, and every fourth day, 68 per cent. It would seem, then, that one repetition every second or third day gives a maximum value for learning.

This law has been tested a number of times on children and adults, and even on the learning of animals, and always with the same results. Ulrich[2] found that white rats could learn a maze with fewest repetitions if they were given one trial each third day. It holds also for sense material as well as for nonsense syllables. The explanation of the

[1] Perkins, British Journal of Psychology, Vol. 7, p. 253.
[2] Watson, Behavior, pp. 228 ff.

advantage of divided repetitions was suggested by some of the experiments of Jost. He found that, when he compared the number of repetitions required to develop completely two sets of associates of equal strength but of different ages, the older set required fewer repetitions than the newer. His method was to learn one series of syllables twenty-four hours before and then to make a few repetitions of another series a few hours before the test. The amount retained was tested by the method of paired associates. When three times as many correct associates could be given from the newer series, it required almost the same number of repetitions to bring each to the point where it could be said through without mistake. When the number of correct associates that could be given was approximately the same for both series, the older series could be fully learned much more easily than the more recent. His theory is that the associations continue to grow strong, to 'set,' for some time, perhaps for two or three days after they are first formed. That associations tend to increase in strength for a few days is known as 'Jost's Law.' This unearned increment that comes from the setting process makes it much easier to bring them back to full effectiveness some time after the learning, than if no time is permitted to elapse after the repetitions are first made. It is possible to connect this setting process with the continued activity, perseveration tendency, that constitutes the primary memory or immediate retention. This setting is one more expression of the inertia of the nervous system

Several important practical deductions may readily be drawn from this law. Obviously, it connects well with the preceding law, since, if one is to read through each time, only short selections could be learned in any one day. Coupled with the advantage from divided repetitions, it

gains full force, since, if the selection be not learned at the first sitting, it is an advantage to wait a day or two before proceeding to complete the learning. Again the bearing upon the familiar topic of cramming is quite evident. What is repeated often at periods considerable distances apart is learned thoroughly, while accumulated repetitions in a brief period produce slight effect and one that quickly disappears. This is more certain from the fact that divided repetitions leave much more persistent effects than accumulated. In general, the more the repetitions are divided, up to one every third day, the more permanent will be the learning.

**Rate of Repetitions.** — Other factors that affect learning are the rate at which the material is read and the degree of activity or the degree of attention given it. The rate of repetition has been several times investigated with slightly different results. Ebbinghaus first asserted that the more rapid the rate, the quicker the learning. Ogden modified this by showing that learning was quickest when reading was at the fastest rate possible without too much effort. Part of this difference lay in the fact that Ebbinghaus used the time alone as a measure of effectiveness; Ogden employed both time and the number of repetitions. Meumann, as a result of experience gained from many investigations, concludes that the best rate varies with the individual, the material to be learned, and the familiarity of the learner with the material. It is best to read relatively slowly at first when the subject matter is being understood, and more rapidly later, up to the point where the effort begins to distract.

**Active Repetitions More Effective than Passive.** — The effects of the attention of the reader have been investigated numerically only in one respect, the advantages of passive

reading as compared with active repetition. Witasek made experiments to determine the best combination of reading with attempts to repeat. He found that the most satisfactory result was obtained when he read five times and then repeated fifteen times from memory. Skaggs [1] found it an advantage to intersperse a recitation between each reading rather than to have more than one of each in succession. It is evident that attempting to repeat from memory requires more effort and will hold attention much more than passive reading. It should be said, however, that repeating material that has lost its freshness in an abstracted state, practically without attention, will give rise to learning in a much shorter time than one would think, although it is of course not so effective as repetition with full attention. Still another factor that plays an important part in learning is the intention to recall. Meumann and others found a saving of 50 per cent or more if series were repeated with the expectation of being tested on them later, as compared with similar series that were learned without knowing that the learning was to be tested. Sanford[2] found almost no learning to result from the daily reading of the morning service, without intention of recall.

**Associative Inhibition.** — An important factor in preventing learning is the presence of other earlier formed associations with the syllables to be learned. Müller and Schumann found that, if two associates are made with the same syllable, they interfere with each other, and the second will be learned with greater difficulty. They demonstrated this by learning a series of syllables *a, d, g,*

[1] Skaggs, Journal of Experimental Psychology, Vol. 3, p. 424. Cf. Gates: Recitation as a Factor in Memorizing. Archives of Psy., No. 40.

[2] Studies in Experimental Psychology. Titchener Volume, p. 5.

etc., first with *b*, *e*, *h*, etc., and then later *a* with *c*, *d* with *f*, *g* with *j*, etc. It was found that it took considerably longer to learn the series of syllables when other syllables had already been connected with them than when learned for the first time. In the experiments, the syllables to be relearned were interspersed irregularly, so that the association with the old positions and with syllables, that were near but not contiguous in the first connections, should not aid in the relearning. In practical life this means that when one thing has been learned with another, it will require a longer time to learn it with a second than if it had not been learned with the first. If a mistake has been made, it will take longer to correct it than it would to have learned it correctly in the first place. But where several things are to be learned in the same connection, it is found that inhibition ceases to be effective if the first is thoroughly learned before the second is begun. In fact, in that case there is apparently some saving, since the familiarity with the old saves some work in learning the new. This interference of earlier formed associates with the formation of new ones is known as 'associative inhibition.'

## Retention and Forgetting

**The Rate of Forgetting.** — The investigations of the retention of associations bear largely upon the rate of the disappearance of associations with time. There is a general tendency toward the unlocking of associations that begins at the moment of reading or a few moments later, and goes on indefinitely. Two long studies have been made of this topic, one by Ebbinghaus, the other by Radossawljewitsch. Their results may be compared in the table on the following page.

| Length of Interval | Per Cent Forgotten | |
|---|---|---|
| | E | R |
| 5 min. . . . . . . . | | 2.5 |
| 20 min. . . . . . . . | 41.8 | 11.4 |
| 1 hr. . . . . . . . . | 55.8 | 29.3 |
| 8 hr. 45 min. . . . . | 64.2 | |
| 8 hr. . . . . . . . . | | 52.6 |
| 1 day . . . . . . . | 66.3 | 32.2 |
| 2 days . . . . . . . | 72.2 | 39.1 |
| 6 days . . . . . . . | 74.6 | 50.7 |
| 30 days . . . . . . . | 78.9 | 79.8 |
| 120 days . . . . . . . | | 97.2 |

The main difference is to be seen in the fact that Ebbinghaus found a larger percentage forgotten in the shorter periods. Both indicate a relatively rapid forgetting at

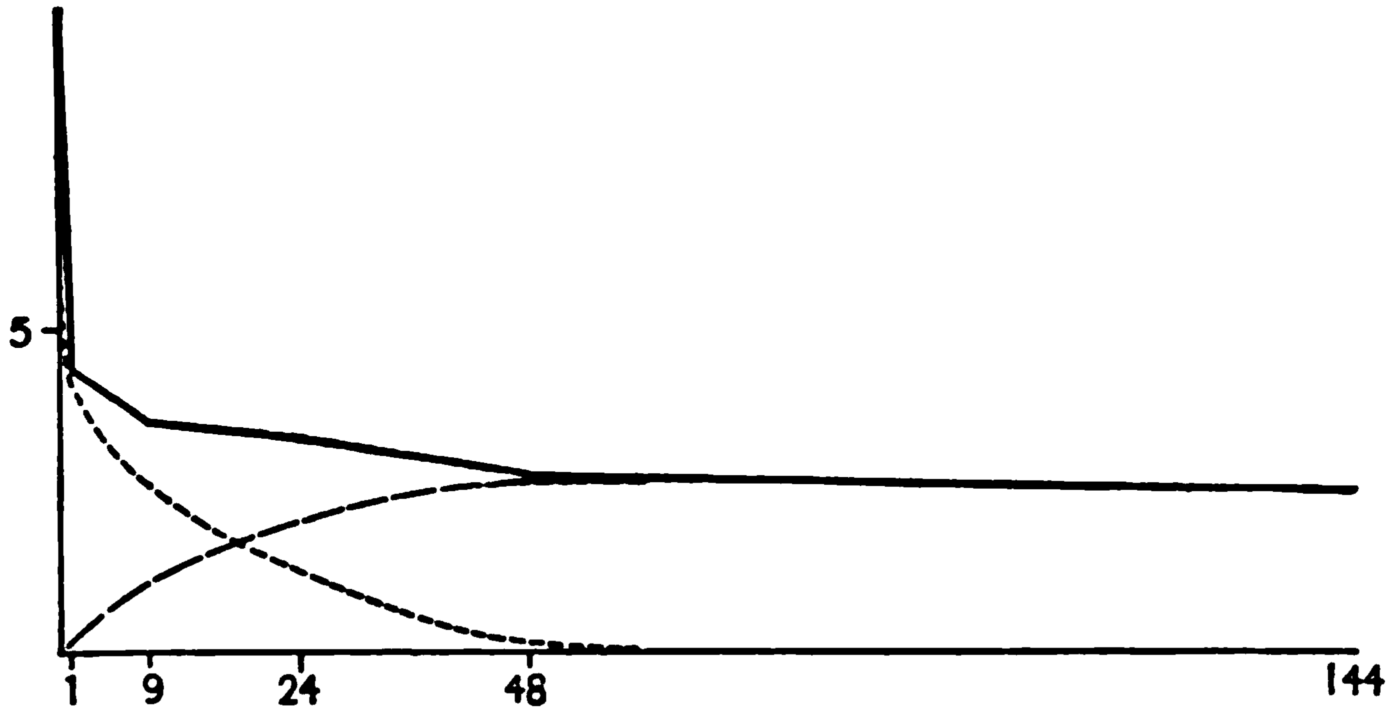


FIG. 92. — Analysis of the curve of forgetting to show possible coöperation of perseveration and association. The full line shows the course of forgetting after Ebbinghaus, the dotted line the conjectured decrease in the primary memory (perseveration) and the dashes the initial increase in the strength of association due to perseveration.

first, and a relatively slow rate in the longer intervals. It should be remembered that nonsense syllables were used and that these are forgotten much more quickly than sense material. Sense material shows a somewhat similar

curve but a much slower rate. The comparative rapidity of forgetting during the first few days suggested to Müller that it was very likely that two factors should be taken into consideration; first, perseveration, or the memory after-image, which diminishes very rapidly and may be regarded as disappearing in the first two days or so, and, second, the associative tendency, which in accordance with Jost's law is to be conceived as increasing in strength for two days or more and then decreasing in strength very slowly. For most purposes the increase in the strength of the associative tendency is masked in the total curve by the rapid decrease of the perseverative tendency, but later the decrease in the strength of association is represented by the curve of forgetting (Fig. 92).

**Retroactive Inhibition.** — The one factor which seems to influence the retention or forgetting process is the series of events which take place in the few minutes immediately following learning. Müller and Schumann were the first to observe that learning a second series of syllables immediately after the first decreased the likelihood of recalling the first. The interval within which the second may interfere with retention is about six minutes. The degree of interference seems to increase with the similarity of content between the two series, but any mental work will be injurious within that period. The effect is greater when the individual is fatigued or in periods of lessened effectiveness, and is also greater when the first has not been too well learned. The explanation of the phenomenon is that the associations are being strengthened during the period of perseveration that immediately follows the learning. If attention is turned to anything else, the perseveration is interfered with, and so associations are less likely to be formed. Memories may also be prevented from 'setting'

by a physical or mental shock of sufficient severity. Frequently after an accident one remembers nothing of the events that immediately preceded the accident and nothing of the injury itself. The shock of the injury will wipe out the effects of the preceding events. This retroactive inhibition is another instance in which we have evidence of the influence of the perseveration through the continuing activity of the cortical cells after the stimulation ceases.

**Is Forgetting ever Complete?** — It is evident from these studies that associations persist when there is little immediate awareness of them, when one cannot bring them back by an associate closely connected with them; when they can be detected only from the fact that they may be relearned more easily than if they had not previously been learned. This fact has given rise to much discussion as to whether anything is ever forgotten. The discussion arose originally from the fact that occasionally long-forgotten events from a remote past are recalled. Coleridge cites the case of a girl, a servant in the house of a pastor who was accustomed to walk up and down a passageway near the kitchen where she was employed, reciting passages from Greek, Latin, and Hebrew authors. Some years later in a delirium of fever she was heard to recite strange words that convinced her attendants that she was possessed of a devil. The physician wrote them down and traced them to works in the possession of the old pastor, now some years dead. If the case is to be accepted, memories that never were consciously developed, and which should have been forgotten if they ever had been developed, may still be lying dormant in the nervous system. Numerous other cases may be cited of the return of experiences long forgotten, usually in case of disease, under hypnosis, or in similar abnormal conditions. These cannot be taken to

prove the thesis for which they are adduced, but they may serve to reënforce the statement that experiences leave their effect for some time after they can no longer be recalled through associations of ordinary strength. Not improbably the nervous system never altogether loses some trace of them. This fact is of more importance in explaining recognition, the control of belief, and similar processes, in understanding which we must appeal to the effect of experiences not definitely conscious at the moment, than as a contribution to the understanding of retention and recall. Memories constantly grow weaker at a rate that depends upon their meaning and interest, and gradually, if not refreshed, reach the stage at which they cannot be revived.

## Recall

Recall, as was seen in Chapter VIII, is always through association under the control of the wider purpose of the moment and of other less conscious factors that constitute the mental attitude or context. To recall any old event it is necessary to have some idea which is in some way connected with that event or has some element in common with it. If we assume the possession of a definite memory with a large number of connections, some one of the connections must become conscious before the memory itself will make its appearance. Usually the desire to remember is either itself an associate of the memory desired or both are connected with a common idea. Thus, when one is asked a question in an examination, the question has been connected with the answer and serves or should serve to recall it. The course of the association is determined by the setting, the context of the question is supplied by the subject in which the examination is held. In practical life

the occasion for the recall is a need for the bit of knowledge. A face presents itself and one knows that the name will be needed when it becomes necessary to make an introduction; or one is reading of the size of a ship in metres, and wonders how long it is in feet, and must recall the table of equivalents. In each case there is always something that makes it desirable to know the thing to be recalled, and this has also been associated with the fact. Not all associates of an idea are actually recalled. The reason for this is usually that the right context is lacking. One may read of the length of the ship in comparison with other ships whose lengths are also given in metres, and as relative size is all that is necessary, the thought of the equivalent does not occur to one. The mental attitude or need of the moment always plays a predominant part.

**Reproductive Inhibition.** — Interesting, if relatively unusual, are the instances in which one has occasion for a fact, is sure that it is known, perhaps well known, but in which one cannot recall it. One may be asked the name of a famous painter, and find to one's astonishment that it cannot be recalled, torture one's memory for it as one may. Frequently after the occasion for it has passed, it will come back without the least difficulty, often when thinking of something entirely different. Phenomena of this sort seem to fall under the head of reproductive inhibition that was established by Müller and Schumann and confirmed by Shepard and Vogelsonger. It was found that, when two syllables were learned at different times in connection with one single first syllable, there was not merely an obstruction to the formation of the second association through the earlier formation of the first, but also an inhibition of the recall of both when the common first member of each pair was shown. The time required for the recall of either is

much increased, while the percentage of times that either will be recalled correctly is correspondingly decreased. It seems probable that something like this happens in the moments of blocked recall of familiar facts. The associations must be present, as is shown by the later recall; but apparently too many associates strive for entrance, and each, through some neural interference, blocks the way of the other. It should be added that there is some evidence, obtained by Bair[1] in his experiments on learning typewriting, that when a series of associates has been fully learned — when one keyboard of the typewriter has been thoroughly mastered — another can be learned in less time and there is no interference between them on recall. Were this not true, there would always be interference. A blocking of recall would be much more frequent than we find it, since practically every bit of knowledge has many associates that might be recalled. The effect of the purpose or attitude is usually sufficient to prevent inhibition. When the context favors one associate much more than another, the way is cleared for it and all others are kept from interfering. Interference comes when the associations are not fully formed, are relatively weak, or no strong purpose is dominant.

Learning and retention depend upon the formation of associations and the degree in which they persist, and recall is likewise through the connections that are formed in learning. It, too, is largely a mechanical process, dependent upon the relative strength of the associations, guided only by the context and the purpose of the moment. The laws that have been given are statements of the conditions under which the associations may be formed with greatest strength

[1] J. H. Bair, The Practice Curve, Psychological Rev. Mon. Supplements No. 19.

and in the shortest time, together with an enumeration of the factors that influence retention and the course of forgetting, and the laws of recall. These conclusions are of value in practice, since the laws hold not only under experimental conditions and for nonsense syllables, but also for sense material under conditions of ordinary learning. But in addition to these laws which apply to the raw materials of memory, the fact that memory ordinarily deals with things as real introduces the elements of meaning and logical interconnection, two factors which are important in determining the ease of learning and recall and the use to be made of ideas. The most important influence of meaning, in fact what first gives meaning to groups of centrally excited sensations, is recognition. By recognition we mean that the idea has been accepted and given a place in the experience of the individual. It is this in large measure that transforms the raw materials into ideas, into objects and events that have a real relation to the past life of the individual and to his knowledge.

### Recognition

It was said in an earlier chapter that practically all mental processes follow the pattern of action in consisting of two distinct parts, one like the 'trial and error' learning of a new movement which induces the state, and the other a process which examines the state and either accepts or rejects it. Recall provides the material in memory, recognition is the process of accepting or rejecting. It affirms or denies in part by assigning a date, — by referring the experience to the time and place of its original appearance. This is in itself a warrant for the truth of the recalled process. Thus in an examination many ideas may be suggested one after another, as the answer to a question of fact. If

questioned, it is usually not until the idea can be assigned to a particular book or to a particular lecture that it will be accepted as sufficiently assured to put down. Recall must be tested and confirmed by recognition before memory is complete.

**The Process of Recognition.** — Recognition applies to objects as well as to ideas or memories, and may be studied equally well with one or the other. When one sees a person one must decide whether he is an acquaintance or a stranger, before one speaks; and if he proves to be an acquaintance and he approaches, it is convenient to know the name and where he was seen before. The process of recognition may in itself be nothing more than the arousal by association of his name or of the place where he was last seen, or of the topic discussed with him at the last meeting. When these associates present themselves one is said to recognize. The explicitness of the recognition depends upon the definiteness of the associations that come to cluster about the face. Memories are recognized in much the same way. When the idea is recalled, secondary ideas are aroused which give the first a setting and a warrant.

An objective study of the phenomena of recognition adds much that must be considered in any theory. As compared with recall, recognition is as a rule easier and induced by fewer repetitions. A student will frequently recognize an answer when given by another in a recitation after he has himself failed. It is easier to learn nonsense syllables to the point where they may be recognized when shown than to the point where they may be repeated. On the other hand, one frequently finds in pathological cases that recognition is disturbed while recall is still almost unimpaired. This is seen in psychasthenia, and in certain cases of insanity, particularly in Korsakoff's disease. The psychasthenic at

times will find everything strange, at other times will recognize objects and people that have never been seen before. Everything seems strangely familiar to the patient. It seems that recognition is a rather more certain process than recall in the normal individual, but is more easily disturbed in the abnormal; in fact it is often the first process to be disturbed in mental deterioration. It is also less affected by work performed after the learning — by retroactive inhibition — than is recall. In some ways, then, it seems more easy to induce recognition than recall, but at the same time recognition is more delicate as measured by the susceptibility to impairment by disease, but is not so readily disturbed by mental work immediately following.

**Experimental Studies of Recognition.** — Experiments were early made and have been frequently repeated on the effects of the passage of time upon the accuracy of recognition. The results fall into two distinct classes which may be represented by two of the earliest workers, Wolfe and Lehmann. Both sought to determine the influence of the lapse of time upon the accuracy of recognition. Wolfe[1] worked with tones which could be made to differ by as little as four vibrations, and had a number of tones at his command, so that they could not be readily referred to a class or given a distinguishing name. He found that capacity to recognize diminished with the passage of time, at almost the same rate as the ability to recall. His curve showed the same form as Ebbinghaus' curve of forgetting; recognition fell off rapidly at first and much more slowly later. Lehmann[2] used gray papers of different shades. At first he used five shades. His subjects at once arranged these in a series and gave a definite name to each. His results showed

[1] Wolfe, Philosophische Studien, Vol. 3, p. 534.
[2] Lehmann, Phil. Stud., Vol. 5, p. 96..

almost no tendency to diminution of accuracy with the passage of time. At first the judgments increased slightly in accuracy and then declined slightly, but there was no approach to the logarithmic curve obtained by Ebbinghaus. When Lehmann introduced nine shades, these were given numbers from one to nine, and the curve retained the same form. Later investigations by Angell and Hayward[1] and by Hayden[2] under approximately the same conditions have given results similar to Lehmann's. The difference in the results obtained by Wolfe and the others may be attributed to the degree in which the material makes possible the association of a word or other familiar symbol. Where no such symbol may attach, recognition is difficult, and ability to recognize vanishes very quickly. When the symbol may be applied, recognition is immediate and persists for some time with no appreciable diminution. Back of the assignment of the name or number is the development of a definite image or notion of the different impressions to be recognized that shall make it stand out for itself and so shall constitute a fixed standard.

This difference between the results obtained by Wolfe and those obtained by the others is similar to the difference between results with nonsense and sense material. A number of recent experiments by Hollingworth, Miss Mulhall, Strong, and others, showed the same difference in ease of recognition between material that has and that which has not meaning. They found in the first place that recognition was much more certain and persisted longer than ordinary recall. It was from two to three times as accurate as recall when advertisements, pictures, words, or other sense material was used. But with nonsense syllables,

[1] Angell and Hayward, American Journal of Psychology, Vol. 11, p. 67.
[2] Hayden, American Journal of Psychology, Vol. 17, p. 497.

recognition had very little if any advantage over recall. If we apply this to our other problem, it is evident that recognition of meaningful material has a very great advantage over recognition of nonsense material. In the one case the shades of gray could be immediately connected with words that had either a definite meaning acquired long before the experiments were begun, or that could be quickly developed for the few shades used. One association alone needed to be formed in order to assure recognition in each experiment. Recognition itself required no more than a decision whether the shade offered did or did not correspond to the standard required. In Wolfe's experiments, no standards were present at the beginning and none could be readily developed because of the great number of tones used, and the slight differences in pitch that were available. Here one dealt with bare association processes formed during the experiments between sensations, neither of which had a meaning of its own. All the preparation for recognition must be made during the experiment, while in the experiments with meaningful material, most of the preparation was completed before the experiments were begun. Meaning, then, contributes much to the ease and persistence of recognition.

**Forms of Recognition.** — Investigators have classified the different varieties of recognition.

> We may regard as complete recognition a feeling of assurance as to the place where the object was seen before, and a recall of all the circumstances of that earlier experience. This is called definite as opposed to indefinite recognition.
>
> In the latter case, one is aware that the thing is familiar but can assign no definite place to it. Many faces are familiar which arouse no name, and cannot

even be referred to a specific time or place. This indefinite recognition is ordinarily due to slight familiarity.

At the other extreme, things which are very familiar are also recognized, but, because of their great familiarity, are referred to no definite place. Here the recognition is taken for granted. This happens with the furniture of a well-known room, with intimate friends, and with events that are frequently recalled. It is an implicit as opposed to an explicit recognition. The objects are treated as if known, arouse a feeling that is different from that aroused by strange objects, but are seldom referred to earlier times or even named.

Still another distinction must be drawn with reference to the way in which recognition takes place. In certain instances one can see how the recognition goes on. A hauntingly familiar memory makes its appearance, but it has no connections and can be given no place. Gradually, as one broods over it, other things are called up by it. Then suddenly an associate, itself familiar, is added to it, and recognition is complete. This may be called mediate recognition, as opposed to the immediate recognition which is much more usual. As will be seen, all of these types have common laws. Those mentioned later are reductions from the complete form.

**The Association Theory of Recognition.** — Theories of recognition are very numerous and in some degree conflicting. One has been already indicated, the placing of the unknown through association with the known. This can be traced empirically very frequently. One hears the title of a book; it sounds familiar, but can be given no place. Gradually, ideas cluster about it until it is placed as a novel by such an author, read on the boat two years

ago; or it may be remembered as the book that was recommended by Jones but which has not been read. Similarly with the recognition of objects. This bit of crystal at first seems to be absolutely unknown; then a background grows up about it; you remember where it came from; that supplies the name and the purpose for which you obtained it, and the whole recognition is complete. The association theory assumes that all recognition is of this type, and that in the cases in which the recognition is indefinite the associates are present and have their effect, although they are overlooked or do not come to full consciousness. They nevertheless provide the mark of familiarity, give a color to consciousness that is accepted as a warrant for the belief that the idea or object has been experienced before.

**Unnoticed Associates May Induce Recognition.** — Even in immediate recognition the associations give the quality of familiarity. Probably the feeling of familiarity is due in the case of these very frequently repeated objects and events to partially open association paths that give recognition without any definite recall of the associated events. When the object is familiar but cannot be definitely placed, it is probable that there are also partially open association paths, but that they do not lead to the meaningful object or to the fixed landmark. The feeling is present with nothing to fix the experience. Similarly, in certain cases in which the recognition is false, when one sees an individual who seems familiar but on speaking finds that he is not an acquaintance, it is probable that something in the person suggests another or calls up associates that are misplaced. Here the associates give the feeling without even warrant in fact. In short, partially open association paths give the feeling of familiarity when recognition is not complete and even when the recognition is not objectively true.

**The Motor Theory.** — Another theory with many adherents is that the feeling of familiarity comes from slight movements awakened by the stimulus or image. This is approximately the same theory as the other, except that the processes aroused are first motor, then sensory. The idea arouses some habitual movement, slight or more intense, and this constitutes the basis of the assurance that the object has been seen before. The movements themselves are not recognized, but because of their arousal the familiarity attaches at once to the object. The best instance of this is to be found in the feeling of 'at homeness' that comes with the use of an old tool or instrument when one comes back to it after a period, as compared with the feeling of a strange one, even if it is of the same pattern. The habits that have been developed in its use are suited to it, and the pleasant feeling of familiarity results.

**The Feeling Theory of Recognition.** — Another group of theories starts with the assumption that recognition is an immediate experience that cannot be analyzed or explained, but must either be accepted as a given fact or be speculated about in general terms. The more definite of these theories asserts that recognition comes because of the pleasure which attaches to the familiar experience as compared with the unpleasantness or neutral quality of the unknown. The pleasure is explained as the result of an instinct. The known is pleasant, since one always makes an immediate response to it. If harmful, one can avoid it immediately; if beneficial, it is pleasant in and of itself. The objection to the theory is based primarily on fact. Not all cases of recognition are pleasant, certainly not all pleasant things are familiar. Another theory in this group asserts that familiarity is an immediate conscious experience, even more primary than either sensation or association. This theory

represents a possible interpretation, if all others fail. The same objections hold against it as those raised against nativism in space. It gives up the problem without attempting an explanation.

**The Advantages of the Association Theory.** — The evidence so far accumulated favors the association theory in some form. Indirect recognition can be traced to associations. In direct or immediate recognition, we cannot detect associations explicitly. Nevertheless, three facts indicate that they must be present. (1) Things that have many associates are readily recognized, while nonsense material — that is, material without associates — is recognized with difficulty, is recognized no more easily than it is remembered. Recognition is aided also by two of the factors that aid association. (2) Meyer showed that recognition of nonsense syllables was more accurate when a syllable with which it had previously been associated was shown, just before the syllable to be recognized was presented. (3) It has been proven, too, that recognition is quicker and more accurate if the individual is in the proper attitude toward the object to be recognized just before it is shown. Just as in everyday life, if one meet an old acquaintance, when one has been thinking about the place where he was known, one is very much more likely to recognize him than if he appears without any preparation. These four facts together indicate that association and recognition are very closely related. Recognition always comes when associates are aroused, and where associates are not overtly present, experiments indicate that conditions which favor the formation of associates or recall by association also favor recognition.

**Meaning and Recognition.** — In any statement of the association theory of recognition, it is taken for granted

that the associates must be themselves familiar or the process will not be complete. Sometimes several links are necessary before a familiar associate presents itself. The familiarity that attaches in turn to the associates effective for recognition and also to the objects recognized immediately is itself due to associates. The difference between the mediate and the immediate is another expression of the difference between the two sorts of recognition that distinguished the methods used by Wolfe and by Lehmann. In Lehmann's form the new is related to some established type,. to something that has been used so frequently and recalled so often that it has become firmly established and thoroughly familiar. These are accepted at once and without question. They are the types that we found necessary to explain perception, and are also the concepts that play an essential part in reasoning. Probably these fixed points of reference for our knowledge are also established and receive recognition through the numerous associates that they tend to arouse but which do not become explicit. Your own name, to take an extreme case, is established more firmly in your mind than the name of another, because of the number of times it has been associated with yourself and with other experiences. Certain events become landmarks in all memory and may be used as points of reference because of the number of associates that have been made with them, and through their frequent recall in different connections. When an event that is at first unplaced can be attached to one of these firmly established incidents, it at once takes on something of its familiarity, in the same way that assignment of the name was all that was necessary in Lehmann's experiments to constitute recognition of the shade.

**Recognition and Cognition.** — Recognition is largely

aided by the types that were found so important in perception, and also by meaning, a process fundamental to thinking of all sorts. The part played by the type and by meaning may be seen more clearly in the more generalized form, cognition. Here objects are referred to classes rather than to particular times or places. It is more frequent than recognition. We are constantly referring all objects that come under our notice to a class. Natural objects are named, tools related to their uses, people are assigned to different races or classes when they are not acquaintances. This process of cognition differs from recognition only in that there is no reference to the earlier experience of the individual, no awareness that the thing has ever before been seen. Except for determining ownership of objects and for our relations with people, it is seldom that we need to do more than cognize. Cognition differs from recognition solely in that the reference is to some class only, some type of objects, with no reference to personal knowledge. The process involves the same factors; a general notion always serves as the point of attachment, but this has a more or less marked series of associations that irradiate from it to give appreciation of its use, or of its special characteristics. In almost every respect it is like the type or concept which we saw to be evoked in perception, and which constitutes what we accept as the real object. Cognition is a reference of the particular object or memory image to a similar typical object or class. Memory is like perception in that it deals with real objects or concepts, rather than with mere centrally aroused sensations.

### Meaning an Aid to Memory

**Meaning in Learning.** — Meaning is not only a factor in making recognition possible but is also an important fac-

tor in all learning. The meaning that the material to be learned has for the individual determines in very large degree how quickly it may be learned and how long it shall be retained. The difference in the amount of time required for learning and the degree of retention between sense and nonsense material is very striking. This may be seen both in primary memory and in learning long series. Ebbinghaus found that school children could give only five of seven nonsense syllables, while of a sentence of 38 words containing seventeen separate ideas, they could remember fifteen of the ideas. For himself he found that with the same number of repetitions he could remember eight or nine times as great a quantity of simple poetry as of nonsense syllables. Meumann obtained slightly smaller values, 7–9 nonsense syllables, 13 words or numbers, 20 words of a poem, and 24 of philosophical prose.

Meaning not only aids in learning but also assures a greater persistence of the material that is learned. The material learned is much less readily forgotten. Ebbinghaus demonstrated the fact for rote memory of verse. In some of his earlier experiments he used a translation of Byron's "Don Juan." After twenty-two years, he found that he could detect a saving of 7 per cent in the time required for relearning stanzas as compared with learning new stanzas. After seventeen years there was a saving of 20 per cent in relearning stanzas which had originally been learned on four successive days. This is to be compared with a saving of 20 per cent for nonsense syllables at the end of thirty days. The retention of ideas is still more complete. General principles, or even interesting events, are frequently recalled after the greater part of a lifetime. Here, however, there is usually repetition or recall in the intervening years.

**Meaning Due to Grouping and to Reference to Systems of Experiences.** — Two reasons may be found for the greater ease of learning meaningful material. First, that to gain meaning the different partial experiences must be grouped about a single centre, must be combined into units, and these units are then remembered practically as single elements. In some recent investigations of a lightning calculator, Dr. Rückle, G. E. Müller found that an essential element of his ability to make calculations very quickly was his capacity for remembering figures, and that this in turn was due to an ability to unite the figures into small groups. Rückle could retain and repeat in any order forty-nine digits. He saw them arranged in seven columns of seven digits each. The seven series seemed to count for him as seven single units. A second element in acquiring meaning, well illustrated by this same investigation, is the attachment of the thing to be remembered to elements of experience already firmly fixed, — an interpretation in the light of old knowledge. Rückle related many of the numbers that he could remember to combinations of numbers with which he was already familiar. Thus he remembered 451,697, because it was made up of the multiples of two prime numbers: $451 = 11 \times 41$, $697 = 17 \times 41$. Six hundred and twenty-four was easy, since it is the square of 25 minus 1.[1] With a large acquaintance with numbers, learning new ones was relatively easy. All material that has meaning has these two qualities. It is combined into relatively small groups. These groups are used over and over again until they constitute practically a unit and they are learned in different connections until firmly established and then can be recalled by many other experiences.

When anything has meaning, it is already connected

[1] Zeitschrift f. Psychologie, Ergänzungsbd. V, pp. 215 ff.

with something that is a part of the fundamental intellectual equipment of the individual. In this, to have meaning and to be recognized or cognized are approximately identical. Thus we found that recognition consisted in attaching to the object or idea that is to be recognized some mark in itself familiar. The permanency of recognition, then, becomes the permanency of the older acquirement. In learning material that has meaning, the same factor is even more prominent. When the meaning of anything is understood, it is by that very fact united to the already familiar, becomes an instance under a general law or a general class, and that gives it in large degree the permanence of the general law. The meaningful material, by virtue of the fact of having meaning, will then be sure to belong to a larger group and so become easier to learn, and will also be connected with something that is already known and which permits the new to be understood. These two characteristics alone would go far toward explaining the advantage for learning of sense material.

The importance of meaning can be seen to still better advantage in the type of learning most frequently practised in adult life, learning the substance without the words. In this there must be some connection with a wider knowledge, or nothing can be retained. Almost anything that is understood can be retained for a little time, and to understand is, in essence, to connect the new with the previously organized knowledge. The degree of retention depends in part upon frequency of repetition of the ideas, but much more upon the number of different ways in which the new is linked with the old, and thus to the completeness with which it is understood. While the process of understanding is more important on the whole than the formation of discrete associations, both must be pres-

ent in some degree. Meaning has a basis in association, as has been pointed out, and, on the other hand, frequent repetition, even of nonsense syllables, tends to give them some meaning, however slight. For practical purposes they are usually opposed. In rote learning, only the associates between the elements are considered; in sense material, the connections with the more general knowledge are emphasized. When one is learning by rote, the meaning of the material may be lost sight of; in sense learning, the words may be altogether neglected. Either can be trained at the expense of the other. Individual differences in the use of one or the other are matters of training, and it is possible to acquire the ability to use either at will.

## General Aspects of Memory

**Individual Differences in Memory.** — Not merely is there a difference in the degree to which rote and sense memory may be used, but there are differences in the capacity of learning in general and in the aptitude for learning different kinds of material. One of the most discussed is the difference between quick and slow learners. Ebbinghaus asserts that there is a law of compensation in learning in that, if one learns slowly, one also forgets slowly. The instances chosen prove only that there is a greater percentage of saving for the slower learners, but the number of repetitions required for relearning is least with the quick learner, and not so very much greater for those who learned more slowly in the beginning. Later experiments indicate that the quick learner is more effective in every respect. At the best, then, the slow learner has an advantage only in the percentage of repetitions saved, not in the amount that may be recalled by associates or in the time required for relearning. In several of the cases given, a

quick learner would learn and relearn twenty-four hours later in fewer repetitions than the slow learner required for the first learning.

**Dependence upon Age.** — The dependence of memory upon age is fairly well established. Measured by either the memory span, or the quickness of learning, or the immediate retention, memory increases gradually to thirteen, then improves very rapidly to sixteen, and then more slowly to a maximum at twenty-two to twenty-five, then apparently persists approximately unimpaired throughout life, or at least until the onset of senile decay. Meumann grants that children may retain material once learned rather better than adults, a fact which accounts for the large percentage of our memories derived from early childhood; but both immediate memory and ease of learning are greatest after maturity has been attained. Another factor that may be regarded at any moment as an individual difference, although it may depend upon habit, is the tendency to remember meanings or to remember by rote. This accounts for part of the apparent advantage of children. They are accustomed to learn by rote, and for that reason do it relatively better than do adults, who are at once lost in the meaning, and find difficulty in forcing themselves to attend to the words. The power of rote learning can of course be cultivated, and adults who have cultivated rote learning have an advantage in this also.

**Dependence upon Types of Imagery.** — Still another more truly individual characteristic is to be found in the dependence of memory upon sensorial type. An individual of a visual type is probably more successful in remembering words, colors, landscapes, and similar material; an individual of the auditory type, in remembering musical memories of all sorts, and the order of material that is

learned. Which type is absolutely the best is not known, since investigations have not extended to a sufficiently large number of individuals. Meumann asserts that the visual memory is best for the retention of the elements, but that the motor-auditory obtains a more accurate grasp of the whole. In the work of the arithmetical prodigies or lightning calculators, differences in memory type play a considerable part in determining the character of their feats. Two that have been studied, Diamandi and Dr. Rückle, were visual in type, and one, Inaudi, was auditory-motor. The motor type did not lend itself to the reversal of operations, but with simpler processes was much quicker than the visual. On the whole the motor memory was quicker as far as it went, but much less flexible than the visual memory. When space factors entered, the visual far outstripped the motor-auditory. These are but illustrations of differences in capacity that depend upon the memory type.

**Economy of Memory.** — If one be asked how to learn to the best advantage, or how to improve one's memory or capacity for remembering, the best answer is to apply the rules given under the different heads of this chapter. If material is to be learned by rote, it is essential that there should be a large number of repetitions. In any case the repetitions should be divided over as many days as possible and should be made by the whole method, and not part by part or bit by bit. The units should be grouped into wholes as far as possible, since this grouping reduces the work that must be done in learning. Above all, however, wherever the material to be learned has any meaning, it is essential to understand it. Material understood is more than half learned. In the process of understanding, it is well to approach the material from as many different

points of view as possible. The greater the number of points of attachment, the more thorough is the understanding, and also the greater the number of connections by which to arouse the memory in recall. Where matter is to be learned by rote as well as in substance, it is well to make two or three repetitions to understand the material, and then to proceed to commit to memory by repetition. It is essential also to attempt to repeat unaided as soon as possible. Usually after four or five repetitions, a free recall should be begun and frequent tests made of the parts that are least well recalled.

**Memory Systems.** — Numerous attempts have been made since classical times to develop methods of aiding memory. Latin orators made use of the device of picturing their orations upon the walls of different rooms of a house, one part on each wall of a room, and larger units in the same room. As they proceeded, they would picture themselves as walking through the house and reading their various headings from the walls. A more modern form of mnemonics, but one that goes back several centuries, consists in forming series of links, based upon chance associates between any two things that are to be recalled together. Thus one may remember that Δ is the Greek letter delta by the series: triangle, pyramid, Nile, Delta. Or it may be remembered that Denver is the capital of Colorado through the lingo, Colorado, dodo, bird, dense air, Denver. Similar connections are made by these systems between any two facts that are to be connected. Obviously any scheme of this kind will, in the long run, prove more harmful than helpful, as it involves making four or five associates where only one is needed, and the others are likely to develop inhibitions as well as waste time. It is much better to trust to forming the associations directly,

and better still, if connections are needed, to base them upon some fundamental general principle. The system of the sciences is from one point of view merely a vast mnemonic system, a means of bringing a large number of isolated facts into connection with each other in some logical way. To make use of that as a means of remembering is to follow a plan that has been developed by the best minds of all times, rather than some chance scheme that has been hit upon by a charlatan.

**Transfer of Training.** — A question of practical as well as theoretical interest is whether exercises in learning may be said to train memory, whether training in learning one sort of material or under one set of conditions is transferred to learning some other material or under another set of conditions. All experiments in learning under experimental conditions show important improvement with practice. There is also some improvement when one practises on nonsense syllables and tests by the capacity to learn sense material or by any form of rote learning. It has sometimes been held that memory was something that could be trained in and of itself like a muscle. Practically all modern evidence favors the view that the improvement is really in the methods that are used in learning. One becomes accustomed to attending under the peculiar conditions of the laboratory; one forms, consciously or unconsciously, good habits of study, learns to read with the intention of remembering, and these factors may be carried over to any other material with advantage. From what we know, this is the only sense in which memory can be improved in any general fundamental way, and this is sufficient to account for the improvement actually demonstrated. Another form of improvement can be noticed in connection with sense material, a form that comes without

effort and is a necessary part of all learning. This is the increase in ability to understand, which develops with increased knowledge. As knowledge accumulates and is well ordered, more points of reference develop and each of these serves as a peg upon which new facts may be hung. Just as Dr. Rückle's new numbers could be referred to numbers known as the squares and cubes of small numbers, and could be remembered in terms of those, so a new fact that can be given a place in the system of knowledge, as an instance of a familiar principle, is readily remembered. This system of knowledge grows with learning, and as each addition to it is preparation for new acquirement, all learning may be said in this sense to train the memory.

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# CHAPTER XIII

## REASONING

CLOSELY related to memory is reasoning. Two processes are ordinarily included under reasoning. The first is the construction in idea of plans and machines that may later be applied to actual practice and built of real material instead of in idea. The second is a process of understanding and explaining natural events and phenomena.

**Reasoning as Planning.** — In the first case we have a desire or need which must be satisfied or supplied and for which none of the objects which are immediately seen or can be remembered will suffice. This is the process which is typical of invention and discovery, of planning and designing. The thought constructions save the time and materials which might be wasted in hit or miss trial. When a house is to be built, it is first thought through in detail or drawn with the different spaces allotted as they should be and the different materials decided upon. Then when the actual construction begins many at least of the different problems are settled. The other unforeseen difficulties that appear in the adjustment of various details are also first settled in thought.

**Reasoning as Understanding.** — The second type of reasoning is typical of the attempts to understand natural phenomena or other events. It aims not at changing the course of the world directly, but at seeing why it works as it does. Of course ultimately this understanding of the processes of the universe may enable us to change them

in order better to comply with our needs. The process of reasoning with the end of understanding is typical of science. The immediate ends of science are to understand. The two processes of reasoning are much alike in the incentives which induce them and in the method which is used. Still it is well to recognize them as distinct.

**Reasoning always Arises from a Thwarting of Progress.** — Both forms of reasoning are occasioned by the feeling of need of change in a present condition. In the more active type — that of planning — we feel that the present situation leaves something to be desired, and by reasoning we attempt to find a means of supplying that lack. In the second type — that of understanding — we feel puzzled over some occurrence that does not seem to run in the regular course, and we seek an explanation. Both may be said to arise from a thwarted purpose. In the first the thwarting comes from an inability to attain a desired end; in the second there is a failure to see why the particular event runs as it does. As an illustration of the first we may take the need of making a balky automobile go; of the second type, an inability to understand why the sun rises in the north in the summer while we have always been told that it rises in the east. In both cases problems may present themselves as vague complexes, as mere feeling that something is lacking and must be supplied. The initial active step in either case is to become definitely aware of exactly what is wrong. This is known as the process of judging. It consists, in either form of reasoning, in referring the felt need or the observed fact to a definite name and group of phenomena. To understand why the car stops it is necessary to examine part by part in the light of a knowledge of the machine or of experiences with other machines which have stopped in the past. The particular difficulty may be

discovered upon examination to be due to a broken wire in the ignition system. This constitutes a reference of the vague general fact that the automobile has stopped to a defined class of reasons why it should stop. Similarly, the fact that the sun rises out of place or that it shines into a north window early in the morning leads to an appreciation of the general fact that it does rise far north in the summer and that this needs explanation.

**The Active Steps in Reasoning.** — In each case, after the phenomenon has been discovered or explicitly indicated, the active process of reasoning begins. The first step, when reasoning is viewed as planning, is to find some way of remedying the situation. This is always the longest and in many ways the most important operation. It consists in casting about until some idea occurs that will promise to supply the defect. After an idea has presented itself as to how the result may be achieved it is still necessary to convince one's self and often to convince others that the suggestion is correct, and that if put into application it would produce the change desired. This is the process of proof, and is the process that has always attracted most attention. It is the process that the logician identified with reason, although it is the one that is least active, and in many ways the least important. Reasoning, as we have said, always arises from a thwarted purpose, or felt need. The first stage, after this need is felt, is to analyze this need, to discover clearly what is wrong; this is *judgment*. Then one must find a solution; this is *inference*. Finally it is necessary to show that it is actually a solution; this is *proof*.

These various processes involve many of the association and other mental processes which have already been considered. In addition there are three fundamental facts

or phases that have not been fully considered which are involved at each stage of reasoning, which we must discuss here in detail. These are meaning, the concept, and belief. *Meaning* is important, since almost all thinking is in symbols, in language, or in ideas, that mean something different from what they are in themselves. The *concept* is closely related to meaning, since most of the processes that carry the meanings are concepts. *Belief* is important as a preliminary or substitute for proof in the acceptance of a solution, once it has been reached or has been suggested. These terms we may define and discuss as a preliminary to solving the problems themselves.

## Meaning

**Meaning and the Concept.** — Meaning and the concept are in large measure correlative terms, as neither would have any significance in psychology were it not for the other. In its earliest form, meaning is the fact that one bit of mental content represents or stands for something else. A word stands for an object in our thought and may be used in its place in all of our thinking about that object. Meaning tends to become something almost as definite as the object itself. At least it becomes a mental characteristic of the object and a felt addition to the mental state, which is almost as important as, at times even more important than, the mental state itself. A picture or image of a more concrete type may also take on meaning, and come to represent a number of other images or objects as well as itself. In fact every mental state may be said to have meaning, in that it stands for something in addition to itself, and is important to us for what it means rather than for itself. This is the same condition which we found in perception, in that a sensation of one kind represents some-

thing else and that something else really replaces it in our thought. We saw that a strain sensation represents a certain distance, and that when there is a certain strain in the eye-muscles we think of that distance although we do not become aware of the strain itself. A figure drawn with obtuse and acute angles represents a square figure in another plane of space; and we see that square figure, although we do not notice the angles that induce us to make the inference. All these may be regarded as instances of meaning or representation in perception. In each case a sensation or group of sensations represents or stands for something else; and in each case we become aware of what the sensations represent, not of the sensations that are actually given.

**The Nature of Meaning.** — How one idea can thus stand for another needs to be examined more closely. A study of the conditions under which meaning originates indicates that it is at first a mere process of association or connection through contiguity. One idea tends to suggest the other because it has been seen at the same time with it. A man's name serves at first to recall the picture of the man; then it is used in place of the picture, because we are certain that the mental picture may be aroused at any time that we desire to recall it, and we are satisfied with that feeling. Soon it also becomes associated with the capacities and activities of that man, and may serve quite as fully to represent him in thought as would the image itself. In fact, it often seems to be a more satisfactory representative of his capacities and other more active and vital aspects of him than is the mental picture of him. It has been more often and more closely associated with him than has the picture, and so when we think of those aspects we may be more likely to recall the name than the image.

This may be true especially of men whom we know through their writings or from reputation, rather than through their actual presence. In such cases, when the man is seen for the first time one may find one's self harking back in thought to the name, to find one's self saying in surprise, this is Ribot. The name in such cases gives meaning to the image.

These associates cluster about the word and seem in many cases to give an entirely different feeling to the word from that which it would have without them. Probably a large part of any experience depends upon these associates. As in recognition, it seems that the associates are frequently aroused in slight degree when they are not sufficiently active to give a direct awareness of their presence. Thus a word with one group of associates will seem to be different from the same word with another group, although the associates themselves may not be definitely in mind. The meaning changes as the partially aroused associates vary. These vary under the influence of the mental context or attitude, as was seen in Chapter VI. This makes possible the use of the same word or sound for entirely different objects and ideas. Such a word as *bar* has a number of altogether different meanings, and they seldom interfere with each other. If one thinks of an attorney, it has an entirely different meaning from that which it has as one thinks of a harbor, or of carpentry, or of a beverage. In each of these cases we may think of the word as a centre of associates which spring up as it enters consciousness. One group will come when the mind is in one attitude, and another is aroused when the mind is in a different attitude. Even when the associates are not definitely in mind, the meaning will be different under different conditions; this meaning, we may assume, is due to the different partially aroused associates.

**Meaning as Conscious Process.** — In order to see clearly that there is a definite conscious process of meaning, we may artificially eliminate the meaning. This can be done, according to Professor James, by staring for a few moments at a word in isolation. As one continues to hold the word in mind, it seems to become a mere group of letters, without any of the meaning that it has as one looks at it casually, or even any of the meaning that was present when the staring began. The 'feeling' of the word is altogether different. One may believe that the associations, that were aroused at first, cease to be active during the long-drawn-out staring, and so meaning with its characteristic quality disappears. In general it seems that much of the consciousness that is aroused by the ideas that we have is due to meaning. We seldom if ever entirely dissociate a sensation or memory from its meaning, and much that we ascribe to the bare element is really due to the associates that it arouses. When we do by artifice divorce a sensation or memory element from its meaning, we are surprised to discover what it is. This is probably another effect of the doctrine frequently emphasized throughout, that nothing comes to mind alone; or, in nervous terms, that an element never acts in isolation.

**Meaning Present when Associates are not Noticed.** — It should be added that, even if we accept the assumption made above — that meaning is due to the awakening of old association paths — nevertheless, meaning persists when we are no longer aware of the associates themselves. This was seen to be true of recognition as well; and recognition, we showed, was due to a similar complete or partial arousing of associations. The matter may go even farther, in that meaning may be present when we are not even aware of the sensation or image that gives rise to the

meaning. One is occasionally aware of meaning something, as when one intends to discuss a topic, although no words or other images are present, or are at least not distinct. This has led Külpe and others of his school and Woodworth to assert that meaning may be a new form of consciousness, independent of all imagery. That one may think in meanings alone is what they call 'imageless thought.' Whether these cases are more than the final stage in the dropping out of associates, which are at first present, has been questioned. Certain it is that we find many cases in perception in which the sensation is not noticed in itself but only for the meaning that it carries. Strain sensations about the eyes are not noticed, but nevertheless they mean distance, and through this meaning we perceive distance. Similarly one is not aware of the sensations in reading, but only of the words seen or of their meaning. In recognition, we noticed that one might have a vague feeling of familiarity when the object that induced the feeling was not definitely in consciousness. All these instances are similar to the case of meaning where there is no image to bear or suggest it. It should in fairness be added that the holders of the theory that meaning is a new and peculiar form of consciousness are not convinced by this criticism. They insist that these are all cases in which the new element is the determining factor in consciousness, and think it needs no explanation.

## Concepts

**The Concept.** — The fact that all ideas have an importance only from their connections, and that all are really representative of something else, leads naturally to an explanation of the concept. Historically, the concept is the element or an element which is important only as it

represents something else. In general, it is defined as a mental process that represents general or abstract ideas rather than particulars. In the beginning we may regard the concept as representative of several different objects rather than of one alone. In this sense all common nouns are concepts. They represent all objects of a class indifferently. This notion of the concept offers no difficulty if we remember that all ideas are similarly representative. They all have meanings that reach beyond themselves. Each word or object has many associates, similar in some degree, which have been added from time to time. The one word representing the object is capable of recalling all of the group of associates, and stands for the members of the group because of the partial arousal of the associates, even when the whole group is not definitely or completely aroused. One has the feeling that one might recall them even when they are not actually recalled, and this feeling or a partial arousal gives the experience that we call the meaning of the word.

**Concepts Represent Abstract Qualities.** — Concepts represent *qualities* as well as *objects*. In many cases the qualities which are represented may be regarded as the characteristics of the objects that render them sufficiently alike to be grouped in a single class. In the recognition of animals as a class, it is the mass of qualities that we call life that makes possible the grouping. We may become aware of these characteristics individually and give a name to each. This form of the concept — referring to a quality — is quite as frequent as the concept which merely represents a class, and in many ways it is more important. After the members of a class have become connected through the possession of some one important quality or aspect, that aspect is selected, given an inde-

pendent name, and comes to stand in thought as a real entity. In many cases the scientist establishes the independent existence of what at first was merely a mark or characteristic of a class. Such are the physical concepts of heat, force, electricity, and magnetism, to mention only a few. How far these would be said to have real independent existence, and how far they are characteristics of a group, is a question which not all would answer alike. Certainly they are not merely class concepts; and, equally clearly, without them a large part of modern thinking and investigation would be much less effective than it is.

**Concept as Type.** — Closely related to this form of the concept, which represents something abstracted from the particular ideas or experiences, is the sense in which the term concept is used as the quality that is represented by the general idea rather than as the mental state that represents it. Thus, force, for example, is something which is never actually experienced in the form in which we think of it. It is an abstraction which we must use if we are to appreciate the physical universe clearly, and which is warranted by the fact that it is a necessity for clear thinking. In this sense all knowledge is made up of concepts. The particulars are the raw materials from which the fully unified system is built. One may picture the system of knowledge as made up of various elements that have been fitted together to constitute a consistent whole. These elements are for the most part not given immediately in sensation, but are the results of various refinements, of various ways of working over the raw materials, until some order is brought into the originally inchoate mass. We have seen the process at work even in perception. As was pointed out there on several occasions, what is perceived is not merely a mass of sensations, nor is it a

single sensation that suggests some other single sensation or group of sensations; it is a type, an organized product of many experiences which have finally given rise to a construct consistent with all of our different related experiences. This it is that is in mind when a single stimulus presents itself. Thus, to repeat our simple instance, we see the top of a table as square, not because it is square on the retina, nor because we have seen it more frequently under conditions that make it appear square than when distorted by perspective, — probably it never has been seen undistorted, — but because all that we know about the table top harmonizes with the assumption that it is square. When tested or measured it proves to be square; a similar surface must be made with right angles, it fits into square corners. It is believed to be square because that assumption fits in with all of our other experiences.

**Development of Concepts.** — It is by this method that most of the notions of external objects develop. Position is a notion that cannot be referred to any single experience. Depth also cannot be said to be merely the sensation of the motion necessary to reach the object, but is rather a concept or type developed through many tests, and accepted because it harmonizes or orders many different experiences. Space in general is a similar type. If we turn from perception to less objective things, the same principle may be applied. The development of the number concept can be followed among the different primitive nations. In northern Borneo, the natives still have no developed notion of number apart from objects. When counting they use the fingers and toes; and when the number rises above twenty, another man is called and the objects are checked against his fingers and toes. The remnants of this counting can easily be traced in the decimal system and in the score.

In this instance the concept carries with it more of the original sensory material from which it develops than do space and position, but in the course of time the separation from the concrete is complete; and, for us, number carries with it practically no implication of fingers and toes except for the use of a few words, such as digits.

*Concepts Alone in the Chinese Written Language.* — Very important as evidence both of the way the concept develops and also of the relative independence of the concept when developed is the written Chinese language. Instead of representing sounds as do the characters in the occidental languages, the Chinese characters represent ideas. In consequence, two peoples like the Chinese and the Japanese, with altogether different spoken tongues, may use the same written language. The symbols in Chinese were originally representative of objects; but, with time, convenience in writing has changed them so that in many cases there is little similarity between the object and its symbol. Very instructive evidence of the nature of abstraction is the way more general ideas are represented. Thus morning is represented by the sun near the horizon; evening by the bird on its nest. Good is represented by the symbol of a woman and a child together. Less gallant is the symbol for treachery, which is three women together; and for strife or dissension, which is two women under one roof. In general it will be seen that an object which is a frequent accompaniment of a general idea comes to represent that idea. Interesting, too, it is to note that the original meaning of the symbols are usually not thought of, when used for these secondary representations of abstract ideas.

**Knowledge a System of Concepts.** — Leaving out of consideration for the moment the question of how the con-

cepts develop, it is evident that organized knowledge consists in its entirety of a system of concepts. When anything can be referred to a concept, we place it, we can use it, we understand. On the other hand, when it is possible to develop a notion or concept that will organize a group of facts, we accept the concept as true, and use it until some new facts appear that are out of harmony with it, when that concept is given up and another substituted for it. Just as in the perception of space, the concept or type is assumed to be real and all else is adjusted to it, so in science or philosophy or in everyday life the concepts are accepted as the reals, other experiences are merely appearance. The systems of concepts are by no means consistent with each other, but must be consistent within themselves. Thus, if one consider the experience of perceiving the table from the standpoint of the concepts of the different sciences, we would be told, on the one hand, that it was nothing but a mass of atoms of hydrogen and carbon and oxygen in different arrangements with a few odd elements thrown in; that its peculiar character depended upon the way the atoms were grouped in the molecules. For the chemist it is this and nothing more. For the physicist the picture changes. Atoms withdraw to the background, and forces come to the front. Gravitational attraction keeps it in place on the earth, and gives it weight. We see the table as a result of the vibrations in the ether which it reflects; and its color is determined by the rays that it absorbs and reflects. If one happens to be talking to a physicist of the latest school, electric waves are substituted for the vibrations of the ether. In any case, explanation is in terms of a system of concepts, however the concepts may differ. The physiologist finds his explanation of the experience in the nervous structure of the eye,

in photo-chemical processes in the rods and cones, in the excitations and responses of the neurones. The psychologist finds the explanation in a group of sensations of strain, of light and shade, of images. These are the types or concepts to which experience is referred, as the psychologist attempts to understand it. In short, our simple experience has been dissolved in a great many different ways, no one of which leaves anything of the original experience; and yet without this dissolution into concepts, it could not be understood.

**No Understanding Without Concepts.** — Without concepts all would be confusion. This is clear from a study of the early languages and the lower forms of human thought. It is asserted that among the lower South African tribes there is no notion of direction in the absolute sense. The individual gropes his way from place to place by memory of each landmark along the way, and has no idea in which direction he is going. He cannot keep his bearing even with reference to the rising or the setting sun. How confused his notion of the world must be, can easily be appreciated. Similarly, where numbers are restricted to a score, where length can be measured only in paces, or in days' journeys, and other concepts are equally faulty or altogether lacking, all thought must be decidedly vague and uncertain. Even the use of purely personal concepts of force, as in the explanation of the winds and other natural phenomena by spirits, and the generally accepted anthropomorphic explanation of events and causes, means that little progress can be made toward accurate understanding or use of natural forces. Adequacy of concepts means adequacy of understanding, and that in turn means successful action and application of means to ends. What experience would be like without concepts one cannot appreciate. It

would be of course a hopeless confusion, like waking from a bad dream into an entirely new environment. Nothing would be clear, nothing would be definite. To all intents and purposes, without concepts there would be no consciousness. Adequate concepts are the handmaidens of adequate thought.

**Concepts Develop by Trial and Error.** — The problem of the origin of concepts as the elements of understanding has been one of the persistent problems of philosophy. We find that the general theories divide themselves, like the theories of space, into those which assume concepts and regard them as determining the course of development of knowledge, and those which would develop the concepts themselves from and through experience. Plato, for example, has in his ideas a system of concepts that are innate, the representatives in man of the eternal verities, through which all experience obtains what truth it may have. On the other hand, we have more empirical theories that would derive concepts from the experience of the individual. They regard the more abstract concepts as developed on the basis of individual suggestions worked over and modified to harmonize the experience of the race. This is essentially the suggestion that was made with reference to the types in perception. They may be in part or at times derived by the accumulation of particular experiences that have been consolidated or modified by use. Very largely and in many cases, however, they seem to result from hitting by chance upon some construction that harmonizes with the experiences. When a construction is found that meets this test, it is accepted. Certain it is that concepts are modified with the passage of time and the growth of knowledge, and it is just as certain that a concept is seldom the direct product of the action of the

senses. In the formation of laws, experimental science shows a tendency to consolidate particular observations into generalizations. In this consolidation, trial and error are important factors. However derived, we insist that our knowledge, as used in thought and developed through perception, becomes largely a system of concepts, of types, and that these serve to explain the concrete, and in many cases in themselves to constitute the concrete. Without concepts knowledge would be no knowledge but a mere mass of confusion.

**Concept as Representative Idea and as Type.** — Two forms of the concept may accordingly be distinguished. The first is a definite mental state that means a number of particulars or ~~a number of~~ general qualities of any sort. This takes the form of a word, a typical group of sensations; or it may be reduced to nothing or very nearly nothing but the meaning, the reference itself. The second form is an organized idea, a type that has been proved by tests to satisfy many experiences, and in consequence is accepted as real. It is this concept that is usually meant. It is what we accept as the external object of common sense, it is the fundamental structure or force or principle of explanation in natural science, or in psychology. In many cases these types, too, are not absolutely clearly pictured but are represented in consciousness in some schematic fashion. At other times, as in perception, the types constitute the clearest and most definite structures of consciousness. They are consciousness, and all else is subordinated to them. In every case they are all that we are really conscious of at the moment, whether they be merely meant, or actually reproduced in all their clearness.

**The Stages of Active Reasoning.** — At every stage in active reasoning, use is made both of meaning and of the

concept. Reasoning has as its object either bringing order into experience or discovering ways of improving the environment, and justifying suggestions for new advances. In both cases, reference to the established system of knowledge, to concepts and generally accepted laws, plays a prominent part. Practically all reasoning operations deal with real things or their symbols. Each of the four processes into which reasoning was divided makes use of concepts.

The reasoning process is initiated by the lack of a satisfactory concept or the need for the solution of some difficulty.

In the solution of a problem or in obviating a difficulty, the judgment consists merely in referring the difficulty to a concept. One is prepared to start on the solution when one appreciates what the difficulty is, which involves assigning it to a known class or a clear idea.

The inference, or problem of finding a solution, involves concepts only in that it is customary to try one after another of the familiar concepts to see if they fit. Where an old concept is used, it is used in a new connection if the reasoning is real, and the solution original.

In the final stage, proof, a concept or old organized experience is the factor that induces belief. It is only as one can refer the suggested solution to some system of organized knowledge, to a concept or system of concepts, that conviction of the truth will be induced. As we shall see in detail in each stage, reasoning in all of its parts is possible only through the use of a developed series of concepts.

## The Initiation of the Reasoning Process

**The Initiation of the Reasoning Process.** — Reasoning as a whole must have a positive stimulus. The problem is always forced upon the individual by some inadequacy of old habits or of old thoughts, by something that goes wrong in the ordinary routine. Where habit and routine suffice, one never reasons. Necessity is the mother of all thought, as of all invention. Reasoning results when a man is thwarted in his mental or physical progress. On the mental side some fact presents itself that will not fit into the theories already developed. The number of species of beetles challenged Darwin to discover a reason, the flight of birds and insects challenged Langley and Wright to find some mechanical means of imitating them. Each suggestion that ideas may be realized starts the discoverer on a quest for the means. Granted the problem, the next stage is an analysis of the problem into its elements or conditions to obtain a better understanding of what is to be done.

## Judgment

**Judgment, the First Active Step in Reasoning.** — The first step either in understanding a situation or in finding a way out of a difficulty is an analysis of the situation. This process of analysis consists of a reference of each part of the problem to its peculiar concept or class. The process of reference to a type is known as the judgment. In the solution of any mechanical problem, the building of a bridge, for example, it is necessary to reduce the various strains to their components, to measure the intensity of each, before means can be found for resisting them. In designing a building, the engineer goes beyond the ordi-

nary rule of thumb, determines how much pressure the building will exert downward, how much will be expended in lateral thrusts, what the wind pressure is likely to be at a maximum, and only when these various components of the problem have been determined is he ready to decide what material must be used and how the structural elements may be distributed. Each of these steps is an analysis of the problem into simpler, known elements. The process of analysis is essential at every step in advance of action. It consists in referring the new to old and familiar experiences so far as the new offers points of similarity with the old. This is the first place at which the background of older experience aids in the new construction, in progress of any sort. Only in so far as the problem can be reduced to its parts and the parts referred to established concepts can it be said to be understood, and only then is it possible to go ahead safely. To act before the situation is understood is to act in the dark and ineffectively.

The process of judging consists of the reference of a new experience or an entering sensation to an old concept. From one point of view it is simply the perception process over again. A stimulus presents itself, and, before it is really conscious, it is referred to some old type; it is given a meaning, and thereby becomes fully conscious. The process called judgment by the formal logician is approximately the same, although more explicit and definitely represented in words. Thus 'man is mortal' is a judgment; *man* is the subject, *mortal* is the predicate. The subject represents the presented, the thing given to be understood, and the predicate the concept by which it is explained. The process of judging brings the new under some head or category already established.

**Judgments of Relation and Evaluation.** — In addition to this use of the term 'judgment' to designate the reference of the unknown to some definite concept, psychologists use it also to indicate comparison and evaluation, uses more closely related to that of everyday speech. One is said to judge when one compares two lines; and also when one estimates the value of anything, assigns the money value to a horse or other article of merchandise, or estimates the guilt of the prisoner at the bar. In each case there is approximately the same process. In evaluation of any kind, one has a scale of values that has been developed in the course of many experiences. An article is given its place in the list on the basis of various similarities to things judged before, some explicit, some implicit and indefinite. A similar process is present in judicial decisions. A particular crime is referred to the general scale of crimes and the punishment is affixed in accordance with the scale. Comparisons are also references to concepts, but the concepts are typical relations, not typical things. Relations are as truly concepts as are space or time. The relations of greater and less are typical relations, developed to make it possible to understand certain phases of experience. To measure, it was necessary to develop the concepts of relation in space and time and mass; and measurement is the foundation of civilized life. When an observer asserts that a line is longer than another, he merely looks from one to the other in immediate succession, and the concept greater or less suggests itself; the pair is referred to one class or the other immediately. The process is just as unitary as is the recognition of a new object or any similar classification. The judgment in general is a reference of a new thing or situation to a familiar head, the reference of a particular or unknown to a general type, a

reference that prepares one to treat it adequately. In our specific practical case, it is a process of analyzing the elements of the problem in preparation for its solution.

## INFERENCE

**The Process of Finding a Solution of the Difficulty.** — When the problem has been stated and understood, the next step is to discover a solution. Finding the solution, inference in our sense, consists in a process or series of processes of association. If, when the judgment is attained, the new situation is reduced to familiar elements, the solution is practically completed. The older solutions may suffice or may be combined in the attainment of the new desired end. In these cases, association under the suitable more general forms of control may be all that is necessary. In many other instances the process cannot be reduced to laws, although probably each suggestion is controlled by definite laws of association. One can be sure only that there will be many attempts of different sorts before the solution is finally reached. Inference has more points of resemblance to the efforts of an animal struggling to get out of a box or of the man with a new puzzle than to the ordinary notion of the action of a calculating human being. In these cases the process is one of repeatedly trying, with a readiness to reject all but the right solution.

**Inference a Process of Trial and Error.** — When a person tries to solve a puzzle, he makes one movement and than another, until finally by chance he is successful. In thinking out the solution for a problem very much the same process is used except that the trials are only in thought. One thinks of one after another of the possible positions of earth and sun in trying to find a reason for the

sun's appearance so far to the north (to continue the previous example). If the first one will not work, another is tried. If that is rejected, a third is presented. The process continues until one is hit upon that seems satisfactory. In finding a solution of a difficult mechanical problem, the process of trying suggestions and rejecting them may last for hours, and of course in important inventions the trials may continue for years before the right solution is hit upon. Frequently, an approximation to the solution will be reached, and then the process of transforming or perfecting will go on by the same method for an equally long time before what can be considered a complete solution will be hit upon. In the case of actual inventions or the solution of actual problems, the final satisfaction may come almost by accident, if we can distinguish between accident and intention in such an operation. The list of great inventions that have been made by accident is very long. Almost the only rule that can be given for the attainment of the desired end is to keep trying. Persistence is the only virtue; the rest is very largely a matter of chance. There are certain minds in which ideas spring readily, that seem fertile in suggestions of all sorts; certain others that practically never get away from the commonplace, from the prosaic memories. Blessed is he whose psychophysical disposition is of the former type. The man who happens not to possess this touch of genius can do nothing but substitute persistence and methodical trial for the quick advances of the chosen few. No rules can be given for making the unfertile brain fertile, nor for the better use of the fertile brain.

In the unusualness of the associations and connections that are made lies the one point of similarity between the abnormal or insane brain and the brain of genius. Both

are constantly calling up ideas in connections that would be impossible to the average mind. Tests of the associations of the insane show that their range of associations for a given set of words is very much greater than for the normal man. The results obtained by the man of genius prove the same departures from the commonplace, — in this case called original. The difference between the two sorts of mental fecundity is found in the nature of the originality. In the insane there is little control, the associates are not at all restricted by the nature of the environment, or by any appropriateness to the situation. In the effective man of genius, they are checked and restrained to correspond to the wider demands of the moment. The second still more important difference is to be found in the repression on the part of the normal man of the suggestions that are not suited to the occasion. The speech of an insane man may be merely a 'word salad,' an outpouring of words in any connection; in the normal these absurdities are inhibited, and if they present themselves at all, only those are uttered that pass the censor of common sense. Ability to distinguish between the appropriate and the inappropriate is the primary mark of the normal as opposed to the abnormal. This serves, too, to emphasize the stages of the inference. One must first have the suggestion that is to constitute the solution, but must also have the capacity of knowing when the right solution has made its appearance. In this, reasoning is one more process in which we must distinguish between obtaining the suggestion and passing upon it. Sufficient freedom in suggestion is desirable, but absolutely essential is the capacity to appreciate the right suggestion when it comes, and to be satisfied with no less than the full solution.

Sometimes the right suggestion comes by chance, sometimes it appears when thinking of something else, sometimes one is merely fumbling with the object that one wants to improve in some way, and makes the proper change without any preliminary thought, sometimes it is said inventions have been dreamed. Jastrow quotes an instance of an archæologist who dreamed the reconstruction of the results of certain of his excavations and found that they were adequate. It is said that the eccentric on the steam engine was invented by the boy who had been set to open and close the valves when the piston should change its direction. When he saw some boys he wanted to play with, it chanced that he saw a place to put a stick where it would do the work he was doing, so slipped it in and went off to play. Whether the anecdote be true or not it illustrates how inventions may be made. It makes no difference how the suggestion comes, provided it is recognized as appropriate when it comes, for inference is then complete. Obviously it is quite as important to make proper selection from among the suggestions, as it is to have the suggestion. In this respect reasoning is like memory. The associations that arise in the attempt to recall, correspond to the suggestions in reasoning. Passing upon the correctness of the recall found in recognition corresponds to acceptance of the solution. We have seen that this is also true of the typical actions. All learning is a process of hitting upon a movement by chance and retaining it if the results are satisfactory.

## Belief and Proof

**The Nature of Belief.** — It is particularly essential, then, that we should understand this testing or censoring process in connection with reasoning. Two phases may be dis-

tinguished. One, *belief*, is implicit, comes immediately and offers no definite consciousness of the conditions that lie behind it; the other, *proof*, is more explicit, in that it attempts to make clear why the thinker believes, and why others should accept the inference. Belief gives no warrant for itself; a man knows that he believes, but can tell why only from a study of the conditions under which belief makes its appearance. Neither the feeling of belief nor the conditions that compel belief are fully conscious. In fact, the feeling of belief can be described best in negative terms. We believe all that is not doubted, — the persistent, unquestioned presence of any idea constitutes belief. Doubt, on the other hand, comes with alternations in the interpretations, is due to a constant change from one to another of the ways of looking at an object. The cause of the fluctuation is to be found in the changing points of view from which the fact is considered, — in the different complexes of experience that serve to bring up first one interpretation, then another. Thus, if one is considering a general problem, for instance a favorite of the economists — the advantages of controlled monopoly as opposed to unlimited competition, — one will think of the importance of large production, of the encouragement to capital from certain returns, on the one side, and will believe in monopoly; when one thinks of the tendency of human nature to think first of its own advantages, and of the growing callousness of the dictator to those dependent upon him, permission to combine seems undesirable, and belief in monopoly is refused. The checks that come from state control will remove the doubt for a moment until the difficulties in exercising impartial control present themselves, when the old doubt reasserts itself. Doubt is an expression of the conflict in various beliefs, and the beliefs in turn depend

upon the presence of various groups of experiences which make for the prominence of one attitude or another toward the assertion that is questioned.

In its less explicit forms belief seems to be an expression of the harmony of a particular statement with the dominant group of experiences. This may be seen to advantage in the changes in belief as different possibilities are considered. When one is caught off one's guard, when a proposition is viewed in the light of a limited group of experiences, one will believe things which would not be believed under ordinary circumstances. An exaggeration of the condition is seen in the dream, where we may assume that large areas of the cortex are inactive, and only the few active cells control consciousness. Then one will believe many constructions that are rejected as soon as one wakes. The dream need harmonize only with the partial consciousness, but as soon as one wakes it is necessary that it harmonize with all portions. This it fails to do, and it is then at once seen to be bizarre. In the play attitude, or in the artistic attitude as in novel reading, one may voluntarily hold part of consciousness out of action and pass upon the game or the work of art in the light of a partial experience. In this mood the result is accepted as true for the moment, although one is aware that it will not seem true as absolute fact. In general, belief is agreement between the construction of the moment and the total experience. The awareness of the agreement no more implies the presence in mind of all of the facts that are involved in passing upon the experience than recognition implies the presence of the associates that give the entering impression a place in the past, or the meaning of an image involves the full presence of all that is meant. Rather the thing believed merely holds the centre of the stage without

wavering or opposition, and that, with possibly some slight feeling, constitutes belief.

**Proof a Justification of Belief.** — While belief is sufficient justification for a conclusion on the part of the person who believes, the conclusion may not appeal so strongly to the listener or to others. It is this fact which makes proof necessary. Since justifying the conclusion is the one part of the reasoning process that is self-conscious, it is the process to which the formal logician has devoted most attention and which he is inclined to consider the only part of the reasoning process. Two forms of proof are to be distinguished, the *deductive* and the *inductive*. The typical deductive proof is through the syllogism, and this consists, in essentials, of referring the particular conclusion to some generally accepted principle, to a general law that is typical of all others. Just as the judgment consists in referring some particular object or difficulty to a typical difficulty or concept, the proof consists in finding a universal statement under which the particular conclusion that has been obtained may be brought and thereby made to seem true. The mere mention of a suitable general law arouses the peculiar cortical irradiations of associations that excite belief. First it should be said that nothing is proved that is not questioned. For one's self, belief suffices, and for most of the statements of everyday life as they are made to others no proof is necessary. Proof is given only when one hears or fears objection from one's listeners, or when one desires to test the truth of the conclusion for one's self in an explicit form.

**Deductive Proof.** — The oldest and most frequently used form of proof is the deductive. In essentials this consists in referring the new or questioned solution or invention to an old or familiar class. In simple cases the familiar class

is merely mentioned. In more complicated instances the given problem is analyzed into a number of simpler elements and it is shown, as in a problem in physics, that the solution in question makes use of a number of the simpler and more familiar steps. The formal logician has reduced proof to a schematic form in the syllogism. The syllogism is a group of three statements, of which the first contains a familiar general statement which is used to justify the conclusion. The statement to be proved is put last and the two are united by a statement which indicates the relation. The general statement is known as the *major premise*, the connecting statement is the *minor premise*, and the statement to be proved is the *conclusion*. Thus to choose a favorite instance, one might desire to prove that Socrates would die some day by asserting the unquestioned general principle that all men are mortal. This takes the form

| | |
|---|---|
| All men are mortal, | (*Major Premise*) |
| Socrates is a man, | (*Minor Premise*) |
| Therefore Socrates is mortal. | (*Conclusion*) |

The reader can give this argument a setting if he imagines the members of the Areopagus arguing over the feasibility or desirability of inflicting the death penalty upon Socrates. This syllogism might be used either to meet the statement that it was not possible to inflict the death penalty, because of the prominence of Socrates; or it might be made by one who objected to the death penalty on the ground that Socrates would die anyway in the natural course of events and so would not be a permanent danger to the state. It is obvious that the incentive to the syllogism must come from some one who has asserted the conclusion, and has had it challenged. The syllogism is a form of proof, not as is frequently asserted a method of reaching conclusions.

The syllogism is effective for proof just because it connects the new with an already accepted fact or group of facts. When the reference has been made, the belief that attaches to the old and familiar is transferred to the new. The effect seems to be one of arousing masses of old experience which by their very arousal serve to stimulate the belief attitude. The statement can add nothing to the new and must already be known, or it would not be accepted by the man who is convinced. The utterance of the general principle seems to arouse the memories of the older cases and to crystallize them. Belief follows. The essence of the syllogism consists in this reference of the doubted to a familiar group. It may be given less formal expression and be equally effective. James, for example, shows that if one were asked why one placed a bit of match under one side of the chimney of a smoking lamp, the device could be justified by saying that it would admit air. The value of this might be questioned also, to be justified by reference to the fact that burning is a form of oxidation and will not be complete when the supply of air is deficient. If that were questioned, one would be compelled to refer to chemical formulæ. In fact complete proof on any point might require reference through a large number of steps. Each of these might be put in the form of the syllogism. Fortunately, a reference to one more general principle in any brief way usually is sufficient to arouse belief.

**Inductive Proof.** — The other form of proof, the inductive, consists in counting instances, in determining how often the conclusion is true. If in the past a suggestion has worked on every occasion, we are prepared to accept it as true. The effectiveness of this proof lies in the actual study of past cases or in experimental repetition and veri-

fication of the conclusion. From a study of the vital statistics one knows inductively that all men die. One knows that an aëroplane will fly, because it has flown. The whole proof is dependent on assuming that what has happened will happen. In one sense the two proofs tend to come together, since of the empirical proofs only those are accepted which are in every way similar, which can be referred to the same general principle. On the other hand, the general principles that constitute the major premises of syllogisms and the accepted truths are probably in the last analysis derived from experience, but experiences coördinated and tested by particular applications and by their harmony with other general principles. A general principle frequently starts as the result of a few observations, is tested by other observations, then is compared with other general principles that have also been suggested and tested by other single observations, and, if all harmonize, it gradually comes to be generally accepted. In most subjects controversies over general principles are current at all times, because each is in harmony with certain experiences and out of harmony with others. Settlement comes with more accurate analysis of the problem, with more careful study of the facts, and, where experiment is possible, by making crucial tests of each. But in no case is it possible to say that organized previous experience has not had some share in the proof, nor is it possible to assert that observation of particular experiences, induction, shall not have contributed something. When reference to generalized earlier experience is more in evidence, the proof is called deductive; when particular cases, statistics, or experiments play the larger part, the proof is known as inductive; but neither can be completely divorced from the other.

## General Remarks on Reasoning

**Summary.** — That the stages of reasoning may be as we have stated them — (1) the presentation of the problem that comes by a thwarting of the progress of action or of thought, (2) the judgment or analysis of the problem into its elements and the reference of each to its appropriate class or concept, (3) the inference or discovery of the solution by much casting about, and finally (4) proof, — may be seen by a study of the way in which Darwin and Wallace developed their doctrine of natural selection. It happens that in this case two men, travelling independently practically the same course, arrived at the same conclusion, and we have the process recorded by one of them and confirmed by mutual friends. Dr. Wallace,[1] in modestly disclaiming any priority to Darwin in the discovery, traces in a paper before the Linnæan Society the facts that led both to hit upon the idea and to its statement. First with reference to the formulation of the problem:

"First (and foremost as I believe) both Darwin and myself became ardent beetle-hunters. Now there is certainly no group of organisms that so impresses the collector by the almost infinite number of its specific forms, the endless modifications of structure, shape, color, and surface-markings that distinguish them from each other, and their innumerable adaptations to diverse environments. . . . Again, both Darwin and myself had, what he terms 'the mere passion of collecting.' . . . I should describe it rather as an intense interest in the mere variety of living things — the variety that catches the eye of the observer even among those which are very much alike but which are soon found to differ in several distinct characters. Now it

[1] The Origin of the Theory of Natural Selection, by A. R. Wallace, Pop. Sci. Monthly, Vol. LXXIV, pp. 398 ff.

is this superficial and almost childlike interest in the outward form of living things which, though often despised as unscientific, happened to be *the only one* which would lead us towards a solution of the problem of species. . . . It is the constant search for and detection of these often unexpected differences between very similar creatures, that gives such an intellectual charm and fascination to the mere collection of these insects; and when, as in the case of Darwin and myself, the collectors were of a speculative turn of mind, they were constantly led to think upon the 'why' and the 'how' of all this wonderful variety in nature — this overwhelming, and, at first sight, purposeless wealth of specific forms among the very humblest forms of life. . . . Then, a little later . . . we became travellers, collectors, and observers in some of the richest and most interesting portions of the earth; and we thus had forced upon our attention all the strange phenomena of local and geographical distribution, with the numerous problems to which they give rise. Thenceforward our interest in the great mystery of how species came into existence was intensified, and — again to use Darwin's expression — 'haunted' us.

"Finally, both Darwin and myself, at the critical period when our minds were freshly stored with a considerable body of personal observation and reflection bearing upon the problem to be solved, had our attention directed to the system of *positive checks* as expounded by Malthus in his 'Principles of Population.' The effect of this was analogous to that of friction upon a specially prepared match, producing that flash of insight which led us immediately to the simple but universal law of the 'survival of the fittest,' as the long-sought effective cause of the continuous modification and adaptation of living things."

This shows that the problem had been set for both by almost the same conditions and that the solution had been attained in the same way, but the method of proof devoted to the suggestion was altogether different. Darwin spent thirty years in collecting and in writing out the evidence with only one mention of his theory to Sir Charles Lyell. Wallace, on the contrary, sat down at once, wrote a sketch of his theory, and, curiously enough, sent it to Darwin with the request that it be published. On the advice of friends Darwin presented the paper with a sketch of his own theory to a meeting of the Linnæan Society July 1, 1858. Darwin said that even the words of Wallace's paper were so nearly like his own that one might have supposed that he must have seen it before he wrote. Wallace emphasizes the influence of similar circumstances upon the common result:

"This view of the combination of certain mental faculties and external conditions that led Darwin and myself to an identical conception also serves to explain why none of our precursors or contemporaries hit upon what is really so very simple a solution of the great problem. . . . And now to recur to my own position, I may be allowed to make a final remark. I have long since come to see that no one deserves either praise or blame for the ideas that come to him. . . . Ideas and beliefs are certainly not voluntary acts. They come to us — we scarcely know *how* or *whence*, and once they have got possession of us we cannot reject or change them at will. It is for the common good that the promulgation of ideas should be free — uninfluenced by either praise or blame, reward or punishment."

In this sketch Wallace marks out explicitly three of our stages — the arousal of the problem, the hitting upon the solution, and the proof. The second, the analysis of the problem or judgment, can be seen implicitly in the many

forms that the problem took as the how and why of species became prominent at different times. Observation will show that any clearly formulated bit of reasoning takes essentially the same course. Most of the thinking of our daily life, even in important decisions, stops with the implicit belief. The formal justification of the conclusion is not made. However, as we have seen, the unformulated but organized earlier experience is at work in accepting or rejecting these conclusions through the immediate belief processes, just as it is in the more formal operations. The warrant is the same, although the form in which it is expressed is different.

In reasoning, then, we see an advance made upon the accumulated knowledge, but an advance that is always made possible and controlled by that accumulated knowledge. One understands the new presentation and the new difficulties in terms of the organized old experiences, the types and concepts; one obtains suggestions for new solutions on the basis of analogies with the old; and, when obtained, the suggestions for new solutions are justified and tested in advance of actual use in the light of the organized knowledge. While new experiences and new trials are constantly increasing the sum total of knowledge, it is only by virtue of the previous accumulations and organizations that the new can be understood and that one may venture to test the new suggestions in action with even fair assurance of success.

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# CHAPTER XIV

## IMAGINATION AND DREAMS

A LARGE part of our life sleeping and waking is spent in mental processes, intermediate between remembering and reasoning, which passes under such terms as imagination, revery, and day dreams. Even during sleep we have the conscious processes that we know as dreams. These various processes are alike in that they are due to largely uncontrolled associations which continue without definite purpose and give pleasure because of the nature of the constructions. The laws of origin of the imaginative processes are approximately the same as those for memory and reasoning, but the ends and controlling processes are very different. Reveries are evoked in accordance with the laws of association, as are memories and the products of reasoning; but the constructions are new, and consequently cannot be recognized, as the products of memory can. At the same time imagination differs from reasoning in that reveries have, at most, a very limited truth; they are not believed, or are believed to be true only under very special conditions. If we seek the criteria of the group we find it in a lack of definiteness rather than in any positive characteristics. It is marked by the free action of the mental machinery.

**Imagination and Life.** — It is into this type of mental life that we fall the moment we are free from a serious task. It must be confessed that it occupies many of the intervals in serious tasks, in many cases time that should be given

to the duties of life. When the clerk at his desk has a moment he finds himself constructing for himself a world that is more pleasant than that in which he lives. The student, during the uninteresting periods of a lecture, finds his mind wandering off to a world of future conquests, or to imagined changes in his lot. The ploughboy fills his time picturing a state in which he will sit in the house and direct the labor of others, and no longer hold the handles of the plough. The spare time of all alike, high or low in station, intelligent as well as unintelligent, is spent in spinning fancies. Thinking towards a definite goal is a matter of effort, of distinctly greater effort than the purposeless wandering of the mental images.

The types of these imaginings range from passing day-dreams, unrecorded and transient, to the work of the novelist or the poet, and the creations of the painter, sculptor, and musician, on the one hand, and to the great constructive works of the inventor on the other, as the imaginative process merges with reason. If we were to give a complete explanation of these simpler states of mind we would at once have a theory of art, in all of its forms, and of certain of the achievements of the inventor.

## Play

**Imagination and Play.** — One can find an analogy for operations of imagination in the purposeless activities of animals and children, which we call play. Here on the active side we have the same series of tendencies, probably the same control or lack of control that we find in the mental state that we have been describing. The cause of play is, like the process of imagination, the inability to keep still, the activity of the neuromuscular mechanism, that must respond to every stimulus with movement. This

overflow of activity, the inability to remain quiet, explains the constant movement of the child; it does not explain the particular form that the movements shall take. Many of the movements are determined as much by the operations of the laws of imagination as is the mental process itself.

**Play as Instinct.** — Some plays are definitely instincts; but again, as in imagination, the instinct is evoked by a stimulus or situation other than that to meet which the instinct was evolved. Plays are instincts applied, in advance of their actual need, to situations similar to those that will demand their application. The fighting plays of boys, and the playing with dolls and at housekeeping of girls, are both sets of activities which will be called into use later. In these games what is instinctive is not so much the motor response as it is the pleasure that comes in thinking and acting out the situation. There is an instinctive pleasure in fondling, and dressing the doll; but it is a question whether the doll would evoke the instinct unless it were thought of as a child. Not the instinct but the imaginative transformation of the doll into a child, and the change of the situation as a whole into the home situation, constitutes the essential of the play experience. This setting changes, and the reaction with it. The doll may be thrown down or hidden in a basket when the game is over, as a real child would not be. It is a child only while the game is on. This make-believe, with the changes in the character of the assumptions with changing attitude, is what is at the bottom of the play motif. It makes it possible for the child to act out situations which are pleasant to him, which he is not able to attain in reality.

The games give opportunity for the expression of the various instincts. In addition to the household games that are indulged in mainly by the girls and which are

pleasant because of the appeal to racial instincts, we have games of contest, which may permit expression of the primitive fighting instincts, or the plays of skill, which indulge merely the instinct of rivalry, in its varied forms, coupled with the pleasure in acquirement of skill for skill's sake. Any game or instrument which increases capacity, which gives a chance for a struggle with possible assurance of superiority over some one else, is pleasant. The overcoming of danger, the accumulation of real or imaginary valuables, as in games of chance, are pleasant because of the appeal to the individual instincts. The games that involve rivalry and the use of instruments that increase the power of the individual, give a satisfaction because of appeal to the sense of individual importance, and may therefore be classed under the games that appeal to the social instincts. In practically every case the pleasure of the game is instinctive, but it is always itself a product of the imagination which constructs a situation representing some other real situation that would evoke the instincts in question.

### Revery

**Day-dreams Involve Instinctive Elements.** — The same general statements may be made of revery or day dreaming. In the revery, one spends time in permitting the construction of situations in idea that would be pleasing were they present in reality. Some of these constructions are real plans for the future. Many, however, are nothing more than play ideas, in which one thinks merely how pleasant it would be if the imagined constructions should come true. One is pleased by the mere passing of the ideas and has no thought of attempting to make the desired or imagined situation real. Constructions are pleasing because they put the individual into situations where he could satisfy

his instincts. He thinks of himself as rich beyond any degree that his status warrants as possible; he thinks of himself as writing books that would give him renown; he pictures himself as doing deeds of valor on the battle field; or of rescuing beautiful ladies who shall reward him with their love. Self-aggrandizement, success, social appreciation, are all his, in his reveries. They satisfy the same instincts and impulses as do his games, aside from the desire for actual physical exercise and the relief of tension that is derived from motor activity. Like play, it is a process of make-believe; but the make-believe is limited to ideas, it does not extend to action.

**Control of Revery.** — We may assume that the course of the ideas is determined by the laws of association. Each idea that appears and each object that is seen starts a series of ideas, by the mere spread of the impulse to the other neurones that have been connected with it. As a rule mass dissolves into mass in the process ordinarily called association by similarity. Pictures of considerable complexity succeed each other as wholes. The explanation for the succession is the connection formed between elements, just as it is in all recall. There is some degree of control of the recall through the attitude and wider mental settings. The succeeding ideas are in large measure congruous: they all tend to the development of a consistent whole, although the purpose may be little in evidence when the construction starts its course. The idea that shall follow a given idea is determined by the wider setting, the objects round about, and the ideas that have gone before. It is an instance of controlled association, although, as is usual, the control is not in evidence.

The factors most evidently lacking in imaginings of this type are the selection processes which pass upon the results

in both reasoning and memory. In memory, the products of association are recognized, and if they are not recognized as having been present before, they are rejected, and new recall is encouraged by supplying new stimuli to the association processes. One thinks back to the point where one left the main track of recall, and waits for something else to be suggested, or one looks about for some object that will suggest the idea desired. In reasoning, as we have seen, there is also a definite purpose, and one waits for the construction to appear which can be believed to fulfill or satisfy the purpose; the suggestions are sometimes as little controlled as in imagination, but there is always selection from the numerous ideas that present themselves of those that fit the conditions.

**Selection in Revery is through Instinct.** — In the revery the ideas are seldom controlled in their course, and there is little selection. The only choice exerted is in not permitting one's self to dwell on the uninteresting. When uninteresting ideas appear for too long a time, one will either start a new train of thought or go to work. The interesting, however, is not necessarily pleasant. As will be seen, we occasionally enjoy picturing ourselves in adversity, and as overcome by the thrusts of an unkind fate. One usually pictures one's self as overcoming the obstacles and rising to new heights, but one seems at times even to enjoy representations of one's own misfortune. Reveries, from the standpoint of association, are mere trains of thought that run their course with a minimum of control in accordance with the simpler laws of association, subject only to the veto of the boresome.

## The Unconscious

**Freud's Theory of the Unconscious.** — In connection with this and all of the other forms of imagination, from dreams

to humor, we should mention the theory of Freud, which has been attracting the attention, particularly of the physician, for the past two decades. For Freud, the explanation of any mental operation that is strongly emotionally toned is to be found, not in the laws of association which we have emphasized throughout, but in the work of what he calls the subconscious or unconscious. According to Freud, one must recognize two levels of consciousness or mind: one we have been studying so far; the other lies hidden below that, and is not open to observation by the individual. Its action can be inferred, merely, from the nature of the mental processes and the behavior of the individual. The desires of the subconscious are the primitive ones determined by instincts. They are opposed by what he calls the censor, which corresponds pretty closely to what we have been calling social pressure, the influence of social conventions and ideals which will not permit the ideas of lines of conduct suggested and determined by these instincts to rise into consciousness. Freud goes so far as to picture the unconscious as a person, like the conscious self as a whole, which has definite desires, and also can seek different means of accomplishing the desires, some of which are very much like reason. We are to think of mental life as a struggle between two persons, one impelled altogether by instincts in the desire to gratify the individual — and in Freud's theory particularly the racial instincts; while the other lives a life of convention, in accordance with the rules of good form. The latter is the conscious life, which knows its own ends; the former is always concealed, and while its aims are known to itself, presumably, they never appear above the threshold. The upper, conventional mind is the mind we know, or are presumed to know; while the hidden motives come mostly from the subconscious.

## Dreams

**Freud's Theory of Dreams.** — The application of this theory is seen most completely in the explanation of dreams. Dreams, for Freud, are always attempts of the unconscious to force its desires upon the upper consciousness. Possibly it would be more in accordance with the spirit if not the letter of Freud to say that they are a means by which the man as a whole enjoys the thoughts, desires, and memories which are usually the perquisite of the subconscious alone. It seems at least that were the enjoyment limited to the subconsciousness, it might receive quite as much satisfaction in dwelling on the desires, or revelling in forbidden memories alone, and would have no reason to share them with the upper, apparently unwilling, Puritanical over-lord. Whatever the incentive, the Freudians assure us that dreams are vehicles of the thoughts and desires of the unconscious.

But even in sleep the censor is not altogether off guard, and in consequence it is necessary to outwit it by various stratagems. All dreams are asserted to be suppressed wishes. When the wishes are distasteful, the dream actually expresses the opposite of one's real desire, or the dream is clothed in symbols, which seem innocent, but which the unconscious understands to be really sexual in meaning. It is asserted that the joy which the upper consciousness, which does not understand the symbolism, obtains is a vague reflection of the delight of the unconscious. It should be added that Freud insists that the dream usually starts from or is suggested by an event of the preceding day, which serves to recall some experience of childhood which made a strong impression because of its emotional content. For Freud, these experiences are always sexual in character, and

hence always hide behind symbols. It should be said that many Freudians widen the meaning of the sexual to include other closely related instinctive activities and feelings, an extension which obviates certain of the difficulties we have emphasized.

**Interpretation of Dreams.** — The difficulty in interpreting the dream lies in the fact that it may either be a wish directly expressed, or the reverse of the real wish, or it may mean something altogether different, that can be determined by reference to the symbolic relations known by experience to the physician. If, for example, one dream that a friend is dead, it may mean either that one really wishes he were dead, or by opposites, that he should enjoy renewed and abundant health. Since for Freud many common objects have a symbolic meaning, and all mean something sexual, it is always easy to interpret the dream as meaning what the interpreter wishes it to mean. A serpent, a flower, a landscape, a room, falling, are for Freud all sex symbols. Obviously it is somewhat disquieting to tell dreams to a convinced Freudian, as some of the accepted means of interpretation would be sure to make possible a sexual interpretation.

**Dreams Explained by Association.** — The alternative interpretation of dreams is that they are mere association processes, which run their course without the usual controls. Ordinarily the dream starts, as Freud says, with some stimulation left over from the day before. This suggests ideas from the more or less remote past, as Freud asserts, but we may assume that the ideas that come are aroused by the ordinary laws of association.

Dreams may be initiated by external stimuli. Cold water applied to the face may produce a dream of being out in a snow storm, or more complicated constructions.

Professor Shepard reports that in an experimental investigation of the circulation in the brain during sleep, the patient showed marked changes in the volume of the brain as men passing spoke outside the window. The patient was awakened by the experimenter, and reported a lengthy dream of an experience at a party. Numerous similar instances are on record. Freud insists that the external stimulus in these cases serves to arouse the repressed experiences only, and that the main content of the dream is supplied from the subconscious. On the other explanation, the sensations would arouse associations that would follow their normal course, but a course that was not checked or controlled by knowledge as in the ordinary waking state.

**Condensation in Dreams.** — All psychologists agree that dreams are much condensed. They are merely hinted at or represented by the content of the dream. When recalled they are much elaborated. Freud would make the condensation even greater than the other workers, for he believes that the dreamer is not aware of many of the meanings that are implied, but that these must be supplied, if at all, by the physician who interprets the dream by symbolism. Each object has some hidden meaning which can only be elaborated by one who knows all the significance of the symbols. In addition, the important parts of the dream are likely to be displaced, so that they are made to occupy a much less prominent place than they should have, in the interest of throwing the consciousness off the scent. Both condensation and displacement are according to Freud means of concealing the real meaning. The truth is not recognized by the dreamer even in his most complete interpretation or reproduction of the dream. Havelock Ellis and most other writers who are not Freudians, on the other hand, believe the condensation to be a short-hand

representation, for which the dreamer holds the key, and which he elaborates in his recall without knowing that the dream was in short-hand.

### Other Experiences of the Unconscious and a Critique of Freud's Theory

**Freud's Theory of Revery.** — If one transfer the Freudian explanation of dreams to the day-dream and ordinary revery, it would hold here, too, that the imaginary construction was the expression of the subconscious, and that the material of the day-dream, particularly of those parts that give the most pleasure, are to be interpreted by symbols as meaning what they do not seem to mean. It is probably true that some of our day-dreams are the expression of wishes; hardly likely, however, that these wishes are often concealed under the form of contraries. Freud would have certain of them run as symbols, still more take the form of expression of a desire under its opposite, so that one would build elaborate constructions in which one came off second best, or would think of misfortunes befalling members of one's family, when one was really enjoying thoughts of triumph. One may at least say that the dream and the day-dreams have the same explanation, even if one does not decide whether the Freudian or the general association theory is the more satisfactory.

**A Critique of Freud's Theory.** — The objection to the Freudian theory as a whole lies first in his general conception of the unconscious. One cannot know what there is in the unconscious, because by hypothesis it is altogether removed from observation. It is, furthermore, undesirable to give explanations in terms of assumptions that cannot be verified. Again, the Freudian explanation is so general that it applies to everything and therefore to nothing.

It is just as much a question why the unconscious should desire to dwell on sex matters, or why it should desire to forget certain events, as why the conscious should have the same attitude or desire. There is no chance for a specific explanation of any of these mental events when once they are put in the unconscious. Were there any certainty that the unconscious existed, these lacks would not prove fatal. But as long as we have no absolute evidence of its existence, and there is no particular advantage in assuming it, the assumption seems uncalled for. A more serious logical difficulty with the Freudian explanation arises from the very ingenuity of the theory of symbols. The symbols include practically all of the objects that commonly appear in dreams, and they all symbolize the same experiences. If all dreams signify the same thing, and that thing is something that sooner or later is bound to enter into the experience of any individual, it seems to follow that the assumption is proved. When one attempts to show from this that the ideas are really symbols, the proof is absolutely inconclusive. It amounts to nothing more than reasserting the assumption, and then stating that every one dreams in symbols. Brilliant as is the hypothesis, one cannot regard it as established or capable of being established. It has proved of practical value in suggesting means of treating patients, but it cannot be highly esteemed as an explanation of mental operations.

**Freud's Theory of Forgetting.** — The Freudian theory has been extended to explain many other phenomena, in the individual and race. Freud asserts that the disinclination of the unconscious to face certain facts explains many cases of forgetting. When a man forgets an errand, it is because the errand is really distasteful to the dominating subconscious. One forgets the present intended for

the individual whom one does not like, but to whom one feels under obligation. The names of individuals one does not like are forgotten, even when they have been frequently repeated and should be thoroughly learned. Similarly Freud would explain accidents in which objects are dropped and broken as due to a real desire to break the objects. He instances a case in which he had broken a vase in handling. On thinking back he found that the vase was a present from a person whom he disliked, and he believed that the unconscious broke the vase to remove a reminder of the disliked individual. This he regards as typical of accidents, just as forgetting the disagreeable through the intention of the unconscious is typical of forgetting in general.

**Freud's Theory of Wit.** — Not all of the activities of the unconscious are undesirable. Witty remarks Freud would ascribe altogether to the unconscious. Wit always has a bitter element in it. This he asserts is not intended, nor is the probable effect seen by the speaker. The unconscious, with its usual malevolence, wounds the victim when the upper consciousness might be well disposed to him, or at least unwilling to offend the conventions which prescribe considerate treatment for all with whom one comes into contact.

**Symbolism in Myths.** — The symbols of the unconscious have been extended to explain all of the myths of the race. Here the explanation offered by Freud is that the folk mind would dwell by preference upon sex matters, but conventions which develop (their development is not described) prevent the formulation of these stories of deepest interest in direct form. In consequence the early bards and men of olden times who formulated the folk tales took advantage of the device of expressing the ideas in sym-

bolic form, and the psychoanalyst alone has been able to interpret the real truths which they contain. It is interesting to ask how and why the symbols took the exact form that they are assumed to have taken. Jung has suggested that they in some way became part of the inheritance of the race and have been handed down through the unconscious in the same way that the instincts are transmitted through the physiological organism.

The whole belief in symbols is one of the least satisfactory phases of the Freudian hypothesis. There is no way of verifying the hypothesis, because the unconscious can give no direct report. The only excuse for the assumption is that in the treatment of hysteria a patient will now and again report a dream or a day-dream, and when the physician has assumed from the theory of symbolism that there must have been some repressed or forgotten sexual experience, he has been able to confirm its existence, by psychoanalysis. This confirmation is less satisfactory than it would be if any of the symbols meant anything other than sex in some of its forms, or if the physician who believed in Freud would under any circumstance be satisfied with anything other than sex memories as a cause of the disease. It is also difficult to see what pleasure could have been found in myths whose symbolism had remained undiscovered until thirty centuries after the original formulation.

## Art

**Art as Play.** — In one of its aspects all art is to be regarded as a form of play. The novel and the drama are day dreams of the author which by their character are instinctively pleasing to the reading or theatre-going public as a whole. The stories that please are, as a rule, stories

which represent the hero in activities that it would please us to share. We can sympathize with his victories, and with his defeats which are nearly always temporary and which give zest to the final triumph. From the more intellectual side they may be considered as studies of the laws of human conduct, as a result of making certain assumptions and determining what the natural outcome must be. In this sense a novel or a drama is a depiction of the laws of human action, which permits the author to show what a man must do under a series of circumstances, where these circumstances can be worked out free from the many unknown forces which are constantly interfering with the action of the known conditions in real life. This intellectual interest may lead one to find pleasure in the unpleasant ending, thus making tragedy vie with melodrama in appeal.

Sculpture and painting gain part of their appeal from the fact that they put day-dreams in form, and represent the pure conditions of form in a way that frees them from the accessory chances of real life. In part they have an appeal from the representation of the forms that have a native or instinctive beauty. This beauty may come from association with other events or objects that are themselves pleasing; as the proportions of the human body seem to be repeated in many of the structures that please but which do not even suggest the human form. It may be that certain forms have a native attraction, with no need for association to intensify the pleasure that comes from them. Our purpose here is merely to indicate that art has in it certain of the elements of play, in so far as it is a representation of one phase of life under the assumption that it is the whole. This make-believe unites all forms of art with play, as with the day-dream.

We may mention the explanation of the Freudians that

art, too, is a form of symbolism in which comparatively innocent terms, forms and ideas represent the sex factors. The primitive symbols are applied to novels, to paintings, to sculpture, in exactly the same way as to myths. Possible illustrations readily suggest themselves. For the sake of completeness we may assert that the Freudians find the symbols of the dream life embodied in many of the forms of art as in the myth. The method of proof is the same as that for the other applications, in the similarity or fancied similarity between objects depicted in art and the symbols of the dream and myth.

## General Remarks on Imagination

We see, then, that the dream, the day dream, or revery, play, and all the creative arts — in particular, the novel and drama, painting and sculpture — have many characteristics in common. All find their justification primarily in the fact that they please, all are largely random activities, controlled only so far as they lead to a pleasant end, but an end that is not foreseen in advance. All alike, again, are processes that are indifferent to truth. They are supposed to reach conclusions that are at most but partially true; although in art, by pressing home what is true under certain assumed conditions, they may enforce truths that could not be presented in the more complicated realities of life. The results are pleasing because they harmonize with the instincts; and because on the intellectual side they often present the solution of real problems in a way that would not be possible theoretically.

One explanation of the causes that lead them all to take the course they do has been found in the laws of association, the mere connection of neurone with neurone, on the nervous side, controlled by the wider interaction of

large masses of the cortex in checking the elements which do not harmonize with the whole and in furthering the activity of those parts that do harmonize. As in all association processes, we do not know what is coming before it comes. At the most the individual knows what the general end of all the thinking may be or what he would like it to be. If he knew more it would not be necessary to think.

As an alternative explanation of the course of these play types of thought, we have the assumption of Freud that they are results of definite intention on the part of the unconscious. This unconscious we none of us know directly; and did we know it, we would have once more the problem that we have with the conscious as to why its thought processes act as they do. Were it possible to know as much of consciousness as we are assumed to know of the unconscious we would have no occasion for the hypothesis that the latter exists. If we were to assume the latter, we would need the same study of the laws of succession of its ideas as that which we have given of the association processes, if the explanation is to have any value; for an explanation, a study of the laws of connection and of their controls is essential. It is better to unify them and explain them all in terms of a single self, than to assume a second self which would in its turn require the corresponding explanations. There is no sufficient reason for belief in an unconscious.

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# CHAPTER XV

## FEELING AND AFFECTION

The first of the processes that are in part explained and in part presupposed in instinct, is feeling, the tone that colors very many of our mental states. The principal difficulty in the discussion of feeling lies in the fact that the term has no exact and definite meaning, or perhaps more truly has a number of meanings, no two of which are altogether reconcilable, and which are held by different men of nearly equal authority. The term 'feeling' was originally used to indicate approximately the same mental states as sensation. We still use the term popularly as synonymous with the sensations of touch and with organic sensations. It is also used to indicate any conscious state which is relatively vague, for example, to designate intuition as opposed to the more explicit ways of reaching conclusions by reasoning. We also use the term technically for any less definite conscious state. Thus, we talk of a feeling of interest, a feeling of recognition, a feeling of belief, and many similar states. These states are definite enough as ways of being conscious, but their conditions are less in evidence than those of sensation. The term 'feeling' is used popularly and at different times has been used technically for a number of different processes which have nothing in common except their vagueness, either in the state itself, in its reference, or in its conditions.

**Definitions of Feeling and Affection.** — Evidently we cannot use the term in all of the ways enumerated, and

we are the more justified in restricting it by the fact that there is a fair consensus of opinion among psychologists who have written recently that we shall use it to designate a single process or pair of processes commonly known as pleasure and pain, or more accurately pleasantness and unpleasantness. Since the bare feeling is never found alone but is always accompanied by sensation, it is necessary to distinguish the simple element from the complex of sensation and feeling. Thus, in a headache there is a definitely localized sensation or mass of sensations, and in addition we dislike the ache. The dislike itself, or the form that it takes as a mental process, is the affection, the unpleasantness. No one would deny that this is quite different as a conscious quality from the sensation itself. This quality with its opposite is what is defined as *affection*. The complex of affection with sensation is known as a *feeling*. Psychologists thus distinguish affection from feeling for their technical usage. Affection is the bare fact that we find an event pleasant or unpleasant, while feeling is used to indicate the complex of sensation and affection. Thus, in the instance above, the mere unpleasantness of the experience connected with the headache is the affection, while feeling is the term applied to the total experience. What is meant by this state can be understood by all, but can be accurately defined or described by no one. In the attempt to make clear what is meant, we must recall what was said concerning concepts. What we desire to do is to indicate a concept, which, together with the concept of sensation, shall serve to make possible a description of the most general phases of our conscious life, and to which we may refer concrete states as they present themselves. To make this reference is all that can be done in the way of analysis, and it is helpful in all descriptions

and discussions. Sensations or affections are said to be the elements of consciousness, but that does not mean that they are ever found separately. All that is meant is that it is possible to discover in mental states a sensational phase and an affective phase, — that certain states are similar by virtue of the fact that they are pleasant, just as certain others are similar by virtue of the fact that they are green, and still others in that they are square. For convenience, then, we have spoken of sensations as independent existences and shall speak of affections in somewhat the same way, as if affections were elementary conscious states, and that mental states might be compounded out of them as substances are compounded out of chemical elements.

## Affection

**Affection and Sensation.** — In justifying a separate discussion of the affective phase of consciousness, we must meet two objections. First, it has been held that feeling is only a special kind of sensation; second, that affection is not a distinct element at all but merely an attribute or accompaniment of sensation.

**Affection not a Special Kind of Sensation.** — In answer to the first position it should be pointed out that affections are unlike sensations in that they have no special sense organs. Pleasure may come as the result of the stimulation of any sense organ, and displeasure similarly may be the accompaniment of many different kinds of stimulations and may be excited through many different sense organs. The argument for the specific sensations of pleasantness and unpleasantness seems to have been developed on the assumption that pain and unpleasantness are identical. As we have seen, there is a special sense organ for pain in

the skin and other tissues, and if pain and unpleasantness are to be considered identical, the sense organ for both is readily supplied. As a matter of fact pain and unpleasantness do not mean the same thing. Pain is the specific sensation, and unpleasantness the accompanying reaction. One may see this most clearly, perhaps, from the fact that pain is not necessarily unpleasant. Without speculating as to the pleasure of martyrs, we find numerous cases in which slight stimulation of pain spots is pleasant, as in the cold of a bath, or the fascination of pressing gently upon an inflamed spot. While pain in slight intensity may on occasion be pleasant, it is not at all infrequent for unpleasantness to accompany other mental processes in which there is no excitation of a pain nerve. Smells are unpleasant when there is often none of the sharpness that represents the excitation of cutaneous sense ends. The odor of decaying flesh is unpleasant in itself, as opposed to the unpleasantness of ammonia or chlorine, which is in part due to the excitation of pain nerves in the mucous membranes of the nasal passages. Unpleasant combinations of colors or of tones belong in the class of experiences unpleasant in themselves, as do also the unpleasant effects derived from unpleasant spatial and temporal relations, the unpleasant ideas from social wrongs, etc. One finds a long list of unpleasantnesses that cannot be referred to sense pains.

If pain be not identical with unpleasantness, and the pain nerve be not the organ of the unpleasant affection, still less is it possible to find a specific sense organ for pleasantness. It has been suggested that tickle may be the pleasant quality, and that there is a specific sense organ of tickle. This latter statement, however, is very questionable. Tickle spots have now and again been reported, but the report has seldom been confirmed, and has never

been generally accepted. Granted the existence of the tickle spots, the same objections hold to identifying tickle with pleasure as to identifying pain with unpleasantness. Tickling may be unpleasant and many different kinds of pleasure have no resemblance to tickling. Evidently even if we grant the existence of the tickle spots, pleasure must be something more than a peculiar cutaneous sensation, just as unpleasantness is distinct from and in addition to pain.

*Affection is not Localized.* — Other objections to identifying affection with sensation may be made on the basis of the lack of accuracy of localization of the affections. Sensations always have a definite place, while affection is not definitely localized. One is displeased or pleased in no particular part. Exceptions have been taken on the basis of organic sensations, but organic sensations are rather incorrectly localized than unlocalized. Another distinction, which rests on a slightly less certain basis but is probably generally valid, is that sensory processes are more objective while the affective processes are more subjective. Sensations usually are referred to the outside world, while feelings are peculiarly personal, peculiarly one's own.

*Affection and Attention.* — Closely related to this are the differences with reference to the effects of attention and the influence of recall. It seems fairly well assured that attending to a feeling tends to diminish rather than to increase it, while, as was seen, attention increases the effectiveness of sensations. In passing upon this statement, one should be careful to distinguish between attending to the stimulus or to the sensation, and to the mere accompanying pleasantness or unpleasantness. If one think of an aching tooth, the pain is increased and the accompanying unpleasantness with it. If, however, one attempts to introspect, to ask how and why this sensation is unpleasant, one will be

likely to find that the unpleasantness diminishes as one becomes interested in watching the feeling, and it may disappear altogether. An unpleasant situation bravely faced tends to lose much of its unpleasantness. The same may be said of pleasantness. In practice, a constant search for pleasure defeats its end. A pleasure attended to tends to diminish. Lives spent in pleasure-seeking seem never to attain their goal. The only way to make sure of pleasure is to keep in mind some end to be accomplished and let the pleasure come as an incident to its attainment. Keeping pleasure itself in mind destroys it, while attending to the stimulus increases pleasure as well. The objective and subjective difference may be said to be one phase of this influence of attention. Objective processes, when attended to, increase; while a purely subjective process, particularly if that be related in some way to attention itself, would not be increased. If one think of feeling as an effect of attending to a stimulus, it would follow that when attention was not fixed upon a stimulus, at least one condition of feeling would disappear, and the feeling with it.

**An Affection is not Recalled.** — This subjective character of feeling has also been connected with another character or alleged character of feeling, namely, that it cannot be remembered. It is asserted with some warrant from observation that feelings are not recalled. This statement must be carefully guarded and restricted if it is to be accepted. The warrant for it is to be found in the fact that feelings toward an event are likely to change between the time the event is experienced and the time it is recalled. Thus a social *faux pas* that caused extreme embarrassment may later arouse only amusement, and a practical joke that was much enjoyed at the time may be recalled with chagrin. The affection alone is not recalled in these cases, but the

event is recalled, and the feeling aroused depends upon the circumstances at the moment of recall. This does not mean that one cannot remember that one was pleased or displeased on the first occasion; one remembers the fact, but the affection is not reinstated. The memory of how one felt is indirect, is in terms of words or the memory of the expression. The feelings are not reinstated as the sensory elements may be, but are merely represented or meant. The feeling at the time of recall is the expression of the present attitude toward the event rather than of the earlier attitude, the attitude when the event was really experienced.

Altogether there seems little probability that affections are merely separate sensations. Pain and unpleasantness are distinct, and pain seems to be the only sensation which could in any degree be confused with either pleasantness or unpleasantness. Pleasant sensations have no existence; *i.e.*, there are no sensations to which the term pleasantness could always and regularly be applied that do not have a distinct sensation quality in addition. To assume that any of these sensations could be regarded as identical with the feeling qualities is out of harmony with the facts of distribution, as well as with the qualities of both sensation and feeling. The more definitely qualitative differences, the different influence of attention, and the difference in the way they are affected in recall, all reënforce this conclusion.

**Affection not an Attribute of Sensation.** — The second position in criticizing the separation of affection from sensation — that affection may be an attribute of sensation — meets with just as grave difficulties. As Külpe has suggested, it is always true of attributes that when one vanishes or is reduced to zero, the sensation also disappears. Sensations with no affective tone are, on the contrary, relatively

common. A sensation may be indifferent and still be a sensation, while a sensation that has no quality and no intensity ceases to exist. Furthermore, affections have attributes of their own which vary independently of the attributes of sensation, which again is inconsistent with the assumption that affection is merely an attribute of sensation. Affection has duration, intensity, and quality, is unpleasant or pleasant, although it has no extent or position. On the affirmative side of the question, it must be granted that we apparently never have affection without some sensation, and so it is not an entirely independent entity. One never feels vaguely pleased or displeased: there is always some sensation as the occasion for the affection. In certain instances the affection seems the dominant element in consciousness, but slight observation indicates that there are also sensations, usually of a vague organic character, that serve as the excitant of the feeling. But, as has just been said, this same sensation may at times be present in some degree without any accompanying feeling or, on occasion, with a feeling of the opposite character. On the whole, it seems fairly safe to conclude that the qualities of pleasantness and unpleasantness are found in close dependence upon stimulus and sensation, but nevertheless constitute what may be regarded as an independent mental state, or, to speak more conservatively, as a phase of consciousness which cannot be understood if we regard it as merely sensation, or as an attribute of sensation.

Treating our topic from the structural point of view, affection constitutes a type of mental process distinct from sensation but nevertheless dependent for its existence upon sensation, certainly upon the excitations that cause sensations. Pleasantness and unpleasantness come as a result of sensory excitation immediate or recalled, and these

excitations produce sensations at the same time or a little before they give rise to the affections. It is probably true that no excitation gives rise to an affection without also arousing a sensation. The occasional periods of vague well-being or vague ill-being without apparent sensational basis are rare, and in all probability are merely cases in which the affective aspect of consciousness has for the moment overshadowed the sensory. While affection is thus dependent upon the same excitations as sensations and even probably dependent upon the sensations themselves for its existence, it is not a mere attribute or phase of the sensation, as are quality and intensity; rather we must regard it as a separate mental state or process with attributes of its own.

**Qualities of Affection.** — Starting from this assumption, we may consider affection in its relation to the various stimuli, enumerate its qualities and its physiological accompaniments, in much the same way as we have treated the cognitive processes. First, with reference to the qualities of feeling, it may be asserted that there are but two, *pleasantness* and *unpleasantness*. Many objections have been raised to this statement. In the first place, as has been seen, many people mean altogether different kinds of mental processes, intuitions and what not, from those that we have admitted into the class. These we may exclude by mere arbitrary definition. They certainly have an existence and a place in psychology, but fall rather under reasoning and other heads than under feeling. They simply are not sufficiently like the processes we are discussing to make it possible to extend the term to include them. Wundt, using the term in somewhat our way, makes the suggestion that there are many different qualities of feeling, one for each sensation and intellectual process. To this the majority of psychologists stand in direct opposition. The differences

that strike one are due rather to the qualities of the accompanying sensations than to the feeling qualities themselves. If one can abstract the sensational elements from a feeling, the purely affective remnant is always the same — pleasant or unpleasant.

**Pleasantness and Unpleasantness the Only Qualities of Affection.** — To recognize only pleasantness and unpleasantness as qualities of affection is opposed to many authorities, ancient and modern, but the distinctions they draw seem to be based on other than psychological grounds. Thus, the moralist of everyday life draws a distinction between higher pleasures and lower pleasures. One is the pleasure from the simple senses, the pleasures of eating, for example, particularly the pleasures from the satisfaction of the simpler instincts, while the higher pleasures are the pleasures of the imagination, æsthetic pleasures, the pleasures from moral acts. In general, they are the pleasures which society approves, while the lower pleasures are those which are either disapproved or regarded as morally indifferent. This distinction is recognized by every one. It is at the basis of one of Dr. Johnson's favorite distinctions between pleasure and satisfaction. Still it is generally believed not to correspond to any real difference in psychological quality, but rather to a distinction based upon ethical considerations. Sensuous pleasure is believed to be of the same quality as moral pleasure; the pleasure from a pleasant odor, of the same quality as that from a painting by an old master. The difference is to be found in the fact that one is approved by the connoisseur, carries with it a certificate of being beyond the ken of the multitude, and takes an added flavor from that fact, a flavor which may intensify the other quality but is of the same general class or type. Other suggested qualities of pleasant and un-

pleasant seem on analysis to reduce to similar extraneous considerations and to leave but two qualities, pleasantness and unpleasantness. In general, one must admit with Wundt that the total feeling varies with each stimulation and with each sensation or memory or other sort of mental state; however, the variation is not in the affection but in the sensational accompaniments. The pleasantness or unpleasantness is, if we are to believe the introspections of the large mass of psychologists, always identical; and the differences that Wundt insists upon are to be found in the cognitive accompaniments. The differences between sensuous, æsthetic, and moral pleasures or displeasures are in the occasions of the affections, in the cognitive component of the feelings rather than in the affective elements themselves.

## Other Aspects of Feeling

**Other Suggested Pairs of Feelings.** — Wundt and Royce assert that there are other definite opposites of consciousness that must also be classed as feelings. Royce adds two, restlessness and quiescence. The one is said to be characterized by a constantly changing impulse to movement, particularly by a feeling that one must get on to do something else; while quiescence implies an assent to the present condition, a readiness to remain in the condition in which one is. Wundt affirms that there are three pairs of affection which may be regarded as constituting a three-dimensional series. To pleasantness-unpleasantness he adds strain and relaxation, excitation and quiescence. Strain and relaxation are related to the feeling of effort and its lack in attention, — strain appears in expectation, relaxation in realization. Wundt insists that these qualities do not come from the contraction of the muscles and their relaxation, but are as truly affections without assignable sense organs as are

pleasantness and unpleasantness. Excitation arises when one is disturbed through attempting a difficult task, is a component of anger and of certain exhilarating forms of joy. Quiescence or inhibition is an accompaniment of rest, perhaps of lassitude. They, too, are peculiar qualities of affection with no sense organs and no definite relations to the other forms of feeling. These extra pairs were supposed to be accompanied by special physical reactions, but later investigators seem to have pretty clear evidence that the experiments in support of them were inaccurate or wrongly interpreted. On the whole, direct observation seems not to bear out Wundt's contention that these forms of consciousness are feelings. There can be no doubt that the states exist, but they seem to be either directly due to special sensations such as the kinæsthetic impressions, in strain and relaxation, or to more complicated organic processes in excitation and quiescence. These are probably closely related to the qualities of the emotional states to be discussed in the next chapter. In any case they are not affections in the same sense as are pleasantness and unpleasantness.

**Intensity of Stimulus and Intensity of Affection.** — The other attributes of affection call for but brief discussion. The intensity of each quality of affection varies from zero to a maximum that may end in the loss of consciousness. The relation to the intensity of stimulus has been expressed by Wundt in a curve that holds for stimuli of certain kinds, although there may be exceptions. A faint stimulus is usually indifferent. As the intensity increases, a pleasant affection begins and increases to a maximum with moderate excitations, and then drops to indifference, and finally becomes unpleasant as the excitation is increased still more. The point at which pleasantness disappears varies with the

nature of the stimulus. In many cases it is at a very low point in the scale of intensities; for other qualities all but the highest intensities are pleasant. With suitable allowances, practically all sense qualities will be found to correspond with the rule in some degree. It at least approximates a law. In the diagram, the line *a* indicates the increase in sensation by the logarithmic curve in accordance with Weber's law; *e*, the curve of increase in intensity of

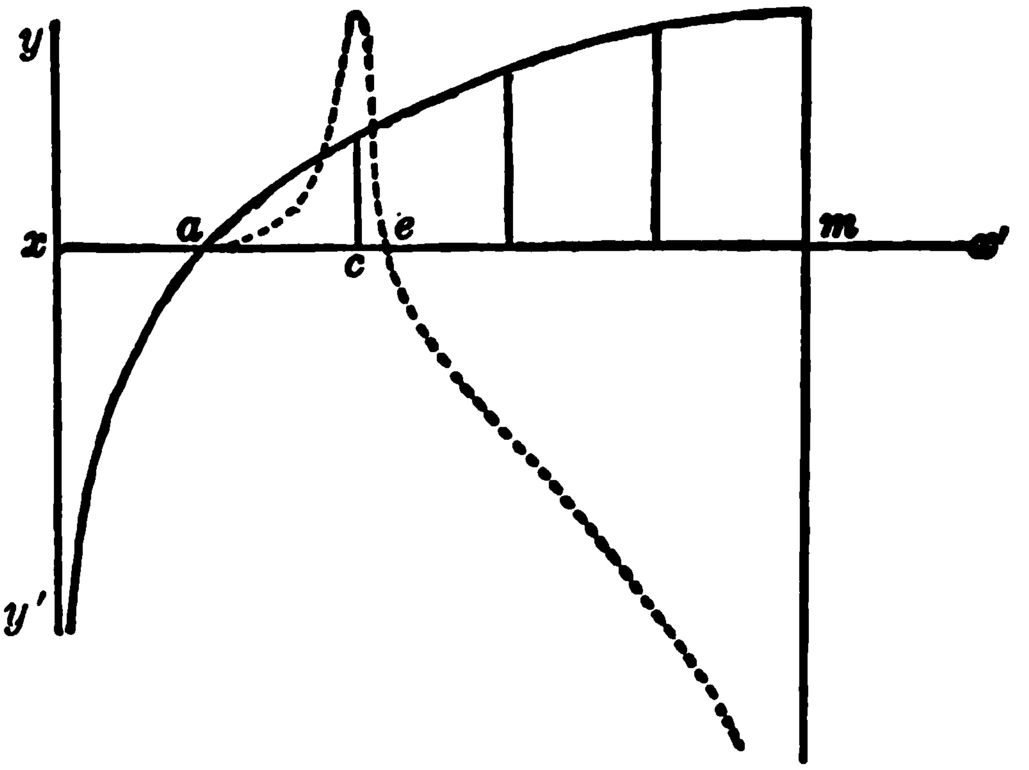


FIG. 93. — Schematic diagram of the relation of affection to sensation. The smooth curve shows the rise of sensation with intensity of stimulus, the dotted line the accompanying rise and fall of pleasantness and the increase of unpleasantness. (From Wundt.)

affection — above the line indicating pleasant, below the line unpleasant affection. The duration of affection differs from the duration of the stimulus both at the beginning and the end. Affection, as has been said, lags behind the stimulus, appears later, a little after the sensation even, in most cases, and may either disappear before the stimulus or change its tone as the stimulus persists. Thus, stimuli which at first are pleasant may become indifferent or become unpleasant if they last too long. Duration has much the same tendency as intensity in this respect, and one might

draw a similar curve. The tendency is always for the feeling to become unpleasant rather than pleasant as its duration increases. No general rule can be given even for the same stimulus as to how great the duration must be before the quality will change.

**Affection and the Qualities of Sensation.** — It would be highly desirable, were it possible, to give either a catalogue or some general law that should classify the objects or stimuli that give rise to pleasure or displeasure. We have already attempted this for the intensity and duration of stimuli. To list the qualities that are pleasant is much more difficult. Experimental æsthetics has made the attempt in certain fields, but the results are too voluminous to be presented in detail, and the general summaries are too few and too schematic to be very satisfactory.

**Bodily Accompaniments of Feeling.** — While one becomes acquainted with feeling primarily through inner observation or introspection, numerous attempts have been made to obtain some record of the behavior in feeling that may serve as a measure of the amount of feeling, or even as an indication of the nature of feeling. It is a matter of common observation that practically all individuals show pleasure or displeasure by certain physical changes. The face is said to light up or to lower, and the general bodily attitude changes in accordance with the feelings. In most cases the presence of pleasure or its opposite can be readily and clearly detected by observation. Many investigations have been undertaken and carried out to translate these simple observations into more accurate measurements. One of the first series of studies was of the changes in respiration and circulation. The first results seemed to indicate that there was a definite opposition in these processes corresponding to the opposition between pleasant-

ness and unpleasantness. Thus Lehmann [1] asserts that in pleasure respiration is slow and deep; while in unpleasantness, at least after an initial inhibition, it is quick and shallow. The pulse, similarly, is said to be slow and strong in pleasure, and quick and weak in unpleasantness; the blood vessels dilate in pleasure, contract in unpleasantness. Later investigations by Courtier,[2] Shepard,[3] and others make it quite clear that the effects depend very largely upon the strength of the stimuli rather than upon the affective tone; that all stimuli tend to quicken the respiration and make it shallow, to quicken the pulse and make it feeble, and to constrict the blood vessels. It is altogether probable that Lehmann's results with pleasure were due to the fact that pleasant stimuli are usually faint, and so if there has been strong stimulation just before, the vital processes tend to return to normal, and thus seem to show changes that are the reverse of the effects of the stimulation. Wundt and his students have attempted to demonstrate peculiar physiological changes of the same sort in connection with his suggested pairs of strain and relaxation, exaltation and depression; but study of their curves indicates that they have been misled by similar phenomena of recovery, and by rhythmic changes that have no relation to the changes in the feeling that they are studying.

**Other Physiological Changes.** — Of the other physiological changes in connection with feeling, the secretion of saliva has been studied most extensively by Pawlow. He found that it was possible to record from the study of the dog many of the changes that result from stimulations which in man are accompanied by feeling and even by in-

[1] Lehmann, Hauptgesetze d. menschlichen Gefühlsleben.
[2] Courtier, L'Année psychologique, Vol. 1.
[3] Shepard, American Journal of Psychology, Vol. 17.

tellectual processes. This he accomplished by dissecting out the duct of the salivary gland in the cheek of the dog, and adjusting it so that the saliva might flow into the pan of a recording scale. It was found that the sight of food or of any object associated with food led to an increased flow, and that the amount secreted was a very good indication of the mental state of the dog. This corresponds to the dryness of the mouth in man in displeasure or excitement, particularly in fear, and the free flow of saliva in pleasure even when that be not associated with food. The opposition between pleasantness and unpleasantness does not hold altogether here, again, since any strong excitement, pleasant or unpleasant, gives the same dry mouth.

Somewhat the same statement may be made of the secretion of tears. Strong grief or displeasure causes weeping, but the brightness of the eye in pleasure is also due to increased secretion of the lachrymal gland which in extreme pleasure may overtax the tear ducts and flow down the cheek.

Slightly better evidence may be given for an opposition in expression in the bodily posture. Grief seems to be marked by a drawing together of all the members, while pleasure leads to an actual physical expansion, — head erect, even thrown back as in laughter, the arms extended and the trunk held straight. These general bodily movements have been much less carefully studied than the others, and the opposition of the different kinds of feelings shown in superficial observations may disappear upon fuller investigation.

We may assert, then, that the feelings show very marked bodily accompaniments, but that these cannot be said to correspond accurately to the differences between pleasantness and unpleasantness, although the degree of our feeling

carries with it an approximately corresponding amount or intensity in the accompanying physical expression. The expression of the feelings merges gradually into emotional expression, which must form a considerable portion of the matter of the next chapter.

### THEORIES OF FEELING

**Difficulties in Formulating a Theory of Feeling.** — In attempting to summarize the facts collected concerning feeling and to refer them to a single principle, many theories have been developed. At present the facts cannot be brought to harmonize with any single general statement; but, rather, different groups of facts may be brought to the support of different statements in themselves not altogether consistent. While no single theory may be said to be true to the exclusion of the others, all taken together give a better idea of the nature of feeling and its relations than can be obtained by any mere statement of facts. The first element that is lacking in the construction of a theory is a satisfactory basis in the nervous system. Each of the other fundamental processes has a definite nervous structure or activity to which it may be referred, and which gives definiteness to the explanation; but affection has neither special sensory nerves to provide it a particular stimulus, nor special central structures that elaborate its materials. Study of pathological cases of disturbances of the affective life in the symptoms of melancholia or euphoria are accompanied, so far as at present known, by no peculiar lesions with which the diseased affections may be associated or to which they may be referred. So far as changes in the nerve tissue have been traced, they are widespread and general rather than closely localized and specific. It cannot be said that one is pleased or displeased

in any particular part of the brain or nervous system, or that affection is carried by any particular nerve or corresponds to any peculiar process.

**Physiological Theories.** — Of the theories, we may distinguish three main groups with several cross lines of division. One of the oldest and most generally accepted makes pleasure and displeasure the accompaniment and indication of benefit and injury to the organism. This takes different forms, either as an expression of an immediate change in the organism in general, of the nervous system as a whole, or of some particular part of the nervous system. It may be an indication of what has been good or bad for the individual or race in the past and is likely to prove so in the future. For these theories, pleasure means that there is in the individual at the moment a process of upbuilding, of anabolism; that this anabolism is induced in the nervous system as a whole or in the frontal lobe, — for Wundt the great coördinating centre for all nervous and mental activity. The evidence for each of these theories is indirect and may be found in the general law that the beneficial is on the whole pleasant, that the injurious is on the whole unpleasant. Correspondingly, when one is physically in good health, well rested and nourished, many activities and even excitations are pleasant which become unpleasant when the physical tone is lower. These facts have been interpreted to mean that action of a well-nourished nervous system or part of the nervous system means pleasure, and that the action of a badly nourished system means displeasure. Taken literally, the identification of pleasure with anabolism, and displeasure with katabolism, would make all action and stimulation unpleasant, since all action involves use of reserve nutriment. The anabolism-katabolism formula has been modified by permitting kata-

bolism within moderate limits, the limits of ready recuperation, to give pleasure. This limit would be difficult to determine empirically, however.

**Evolutionary Theory.** — Another change in the statement of the theory permits the formula to mean a general benefit or injury to the race in the evolutionary sense. This enables one to account for many of the seeming discrepancies between benefit and pleasure. Thus, it seems at first not true, even in general, that the pleasant in food or drink is also beneficial. Aside from exceptions, however, we do use feeling as a guide to foods. We eat what we like, or at least we do not eat what we do not like. The exceptions apply to excesses or to substances of rare occurrence in the environment in which the race evolved. The race as a whole is more likely to survive if it makes use of pleasant but injurious foods, such as sweet poisons, than if it ate no sweets. The exceptions must be learned by individual experience. It is much better to eat than not to eat, in spite of the fact that overeating is harmful. When to stop can be learned from the unpleasant symptoms that indicate injury. Pleasantness and unpleasantness serve as a general guide to conduct, and may be said, metaphorically, to be the expression in the individual of the experience of the race as to what is good or bad. This expression is open to many exceptions, is not a final law, but must be modified by the experience of the individual and the accumulated knowledge of the race. It should be added that the manner in which the experience is recorded and transmitted in the individual, and how and why it acts, are not at all known. The theory is nothing more than a formulation of the general group of facts that, in the long run, what pleases, benefits; what displeases, harms.

**Furtherance-Hindrance Theories.** — Another group of

theories accounts for the more active pleasures largely overlooked in the theories just mentioned. This group couples easy running or unopposed action with pleasure, difficult or opposed action with displeasure. In one form the theory makes real physical movements the basis, in other groups it is taken in a more metaphorical sense. Thus, the first theory states that a smooth, graceful curve is pleasant because the eye will follow it without effort, with a single sweep; while a series of short lines with many changes in direction is ugly because of the difficulty of the eyes in following them.

A slight departure toward the metaphorical is seen in the theory of 'empathy' (Einfühlung) of Lipps, in which the individual does not necessarily have opposed action in his own body, but sympathizes with the figure, feels in unpleasantness that he would have difficulty in doing what he personifies the figure as doing.

Finally, we have Stout's theory that one may have opposition in the accomplishment of an intellectual purpose, in reaching some conclusion in thought; or, on the contrary, one's mental operations may run smoothly or be helped, and so be pleasant. In each of these cases furtherance or easy action means pleasure, hindrance or interrupted action displeasure. As before, one may accept the general statement, particularly in the metaphorical form, although the more specific applications offer much room for doubt and may be disputed as to facts.

**Feelings Dependent upon Earlier Experiences.** — The third form of theory attempts to explain how feeling can be dependent upon such a wide range of experiences, rather than why one is pleased or displeased. The first form of this theory is Wundt's statement that feeling is the obverse of, or at least one phase of, apperception. For

Wundt, apperception is practically synonymous with the active life, covers much of what is treated under attention, perception, and will. It is the effect of the entire earlier experience of the individual in the control of his present action in attending, in interpreting the material offered to perception, in thought, and in practical conduct. This definition makes feeling an expression of the interaction between the coördinated earlier experience of the individual and the present experience. On the nervous side, Wundt gives apperception a seat in the frontal lobe, probably in the front portion of the frontal lobe, and so combines his psychological theory with the physiological in the formula mentioned above, that pleasure corresponds to the action of a well nourished, displeasure to the action of a badly nourished, frontal lobe. This means, or may be made to mean, that whether any process is pleasant or unpleasant depends upon the entire accumulated experience of the individual and in the way that experience is brought to bear upon the process in question, a statement that is undoubtedly true, although somewhat vague. If we replace apperception by attention, and consider the nervous factors that are found to determine the control of attention, we should have approximately the same formula in our own terms.

**Summary.** — We may assert that feeling is an expression of the factors that control attention, an expression of the interaction between the instincts and past experience of the individual, and the present situation. It is an indication of the reaction of the nervous system of the individual, as the result of original endowment and individual acquirement, to the stimuli of the moment. To give an explanation of pleasantness and unpleasantness this formula would need to consider the essential phases of the other two

theories. The theories are mutually complementary rather than exclusive. Thus, the peculiar reactions that give rise to pleasure are indications that the stimuli in question have been beneficial; those that give rise to displeasure have been on the whole injurious, either to the race or to the individual. In the one case we deal with an instinctive response, in the other with a response due to individual acquirement. In the individual acquirement, association with similar experiences or direct connection with other experiences, either in themselves unpleasant or pleasant, plays a large part. One may have the affection of the associated event without having the event itself definitely recalled, as can be seen in the dislike of many foods with which one has had unpleasant experiences, or a liking for colors that have been connected with some very pleasant occasion. The feeling comes, in such cases, without necessarily recalling the event that may reasonably be supposed to have occasioned it. Just what the nature of the reaction may be that gives rise to feeling, why we become conscious in feeling of the nature of the forces that are active in controlling attention, we cannot at present say. The justification for the theory is the far-reaching dependence of feelings upon so much of the earlier life of the individual.

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# CHAPTER XVI

## EMOTION AND TEMPERAMENT

PROBABLY the most impelling and self-asserting mental state of all is emotion. For good or for ill it marks the greatest disturbance in the course of mental events, and is the most personal, the most pervasive. Emotions stand in closest connection with feeling and with instinct. From the feelings they can be distinguished only by the amount of response that accompanies them and by their general complexity. Unpleasantness becomes anger or fear when movements of attack or flight begin, when the muscles of the face and of the internal organs grow tense, and give rise to sensations. On the other hand, many of the occasions for the emotions and practically all of the movements accompanying emotion are instinctive. Emotion may be defined by virtue of these relationships either as a complicated feeling or as the subjective side of the instinct. The list of emotions ordinarily given has varied relatively little since Descartes, and his list can be traced with comparatively few changes to much earlier periods. His list includes: surprise, love and hate, desire, pleasure and displeasure; while in Shand, one of the latest writers who has elaborated upon the classification, we find: fear, anger, joy, sorrow, disgust, wonder, to which McDougall adds the more personal qualities of dejection and elation. These are for all authorities the more fundamental emotions. The others develop from them by combination, by change in intensity, in the nature of the object that arouses them,

or in the time at which the event that arouses the emotion has occurred or is to occur.

## Characteristics of Emotion

**Classifications of the Emotions.** — In any discussion of the emotions it is essential to consider separately two factors: the conditions or causes of the emotions, and the mental content and physical reaction during the emotion.

There are two possible classifications of emotions with reference to cause, although the cause does not necessarily affect the quality of the emotions. Two general causes for emotions have been assigned. One, generally current at present, asserts that emotion is merely an instinct seen from the inside, that the real cause is to be found in the instinctive response. The other, which goes back to remote antiquity, insists that emotions arise from some conflict between ideals or desires and the momentary environment. The first theory applies best to those emotions called out immediately by some external stimulus by virtue of a fundamental characteristic of the organism. Sudden fear at sight of a snake, sudden anger at an injury, the sudden glow of love at first sight, all fall in this class. They need no explanation other than the inherited nervous mechanism.

The second group of theories finds its explanation in the checking of some general movement or current in the life of the individual. In the writings of the older men one finds much difference of opinion as to what it was that moved, but they agree that all emotions arise from a checking or facilitation of the movement, and also that unpleasant emotions arise from the checking, pleasant emotions from the facilitation. For Descartes the obstruction was suffered by the movements of the fluid products of digestion or the blood; for Spinoza the movement was of an unnamed

mental force which was pressing towards a goal of hypothetical perfection. For Shand the impelling force is what he calls sentiment, a force derived in part from instinct, in part from experience, and in part, perhaps, underived, which exhibits systems or groups of forces in ever-widening subordinations. These he divides into the three classes: love, parental sentiment, and the unselfish or social sentiment. When these sentiments find free play or are assisted, pleasant emotions are experienced; when checked or thwarted in any way the emotion is unpleasant. "Every primary impulse . . . when opposed tends to arouse anger; when satisfied, joy; when frustrated, sorrow; and when it anticipates frustration, fear."

**The System of Purposes in Emotion.** — If one is to accept at all this old theory, obviously the first problem is to determine what it is that gives rise to the determining impulse or sentiment, or, in a more conscious sense, the goal of action. As was seen in an earlier chapter, instinct supplies the impelling force, the directing influence, in most conscious processes. To instinct are due the fundamental tendencies. But upon them is built a great superstructure of desires, acquired from education, through living in a particular environment, which serves to differentiate the aims of the individual from his fellows, and characterizes the ideals of the people of one community or social stratum or of one country or of one race. The last two mentioned are dependent in part upon social instincts which make the suggestions and the aims of the group acceptable to the individual. The traits common to all are instinctive; the more particular result from education. Granted that it is instinctive to attain wealth, one must admit that the form that wealth is to take varies from race to race, and the amount aimed at is different for different social groups

within the community. Whether one strives for the wampum or cattle of the savage, as opposed to the bank account of modern man, is a question of environment; as is also whether one sets one's goal at millions or thousands. Similarly, desire for social approval, for what may be called fame, is general, perhaps instinctive, but whether in athletic skill or scholarship, whether in business or in art, in politics or war, depends upon early environment and even upon chance factors in education. Both the sentiments and impulses of instinctive origin and the ambitions developed at the more conscious stage must be assumed, if emotion is to exist. An individual to whom nothing really mattered would be without emotion. The presence of a system of aims makes possible the bare potentiality of emotion; the nature of the aim determines the character of the objects that shall excite the emotions. The emotion itself is an incident in the struggle for the attainment of an end.

**The Qualities of Emotion.** — While one may distinguish two classes of emotion from the standpoint of instinctive purposes which are furthered or thwarted, no corresponding difference can be discovered in the qualities of emotion. From comparing the qualities of the results, it is impossible to say whether anger has been produced by a sudden swift reaction to an act of brutality towards yourself or another, or whether it is the result of being thwarted in a long-cherished ambition. The exultation over obtaining the means of satisfying a long-continued hunger is not different from the exultation over winning an academic honor. No distinction in quality can be made between emotions, however different may be their conditions or origin.

Recent discussion has revolved more about the qualities of the emotion than the occasion upon which the qualities

depend. The descriptions and explanations savor much of ancient theories. These had much to say about the part of the body that was active in the emotion and were very full in their descriptions of the accompanying physical states. Thus, Plato assigned courage, ambition, and the nobler emotions, to the heart; while lust and the baser passions had their seat below the diaphragm. In common observation one may find the explanation of these references in the sensations derived from the general region of the body in which the movements are felt. The changes in rate of breathing, in the circulation, contractions of the muscles of the chest and abdomen, all are noted by the chance observer and are prominent in the novelist's descriptions of mental states. While the modern author no longer ascribes the emotions to the internal organs in the same sense as did the ancients, he still looks to the organic sensations for the coloring of the emotions; in fact, for a quarter of a century, psychologists have been engaged in a controversy as to whether these organic changes do or do not explain both the origin and the content of emotion.

**The James-Lange Theory.** — This controversy began with and has revolved about a theory propounded simultaneously by Lange and James. The theory, stated briefly, is that the movements of the body, when felt, are the emotion; and that the mental factors are altogether subordinate. James states it in the apparent paradox that you are sad because you weep, rather than weep because you are sad. He enumerates a number of cases in which the emotion comes only after the movements have been felt. One may face a situation with no great appreciation of its danger, even with knowledge that it is not dangerous, and suddenly become aware of a trembling, together with a sinking feeling in the abdomen; with this

movement the emotion of fear is fully established. One may look over a cliff with perfect confidence of safety, and then suddenly feel a dizziness and trembling that destroys one's self-assurance and even compels one to draw back involuntarily. In these cases action and thought seem to be at variance, and action takes precedence over thought. The theory in general must be accepted as at least a rough statement of certain facts, and this makes it necessary to examine carefully the opposing arguments.

Obviously the problem revolves about the possibility of discovering instances in which emotions disappear with loss of organic sensations, and instances in which the bodily reactions occur and give rise to emotion when the ordinary conditions of emotion are absent. The first condition was fulfilled by certain hysterical patients who were completely anæsthetic in both internal organs and external muscles. Several of these were questioned in the interests of the theory. The reports agree in general that complete anæsthesia in the parts usually involved in the emotions is accompanied by loss of emotion. One patient, a man who had always been normally emotional, suddenly lost all sensitivity, and immediately thereafter became absolutely indifferent to all that passed about him. He parted from his wife, of whom he was very fond, without any feeling of sorrow, and his reactions to experiences that had previously been strongly toned suddenly became neutral or were lacking altogether. While the fact is generally accepted, Sollier[1] has questioned whether the loss of emotion is due to the disappearance of sensation or to the general reduction in the cortical tone in hysteria. Hysterical patients also suffer diminution of all the higher psychical functions, so that it is not at all surprising that

[1] Sollier, Le mécanisme des émotions.

their ability to appreciate the experience in a way to arouse emotions should be lost. In this case the failure to have emotions would be due to the intellectual defects or to defects in the higher cortical centres rather than to the mere failure to feel responses.

Almost as contradictory results were obtained from a study of actors who were questioned on the supposition that they would provide instances in which the emotion would be felt when the movements were made without any real occasion for the response. A number of famous actors and actresses were asked whether they felt the emotions that they depicted. The answers showed that they were divided into two groups: those who really felt what they were portraying, and a second group who merely carried through their parts as machines. Some asserted that they felt after a performance as if they had actually experienced the events of the play and felt during the performance as keenly as if the scenes were real; the others were perfectly cold. No definite division could be made between the groups on the basis of distinction or success; it seems merely that one group conforms to the demands of the theory, the other does not. James asserts that one must assume that in one group only the external muscles, the muscles of the face and those that give the bodily postures, are affected, while the deeper-lying reactions are lacking. It would seem from this that the sensations essential to the complete emotional experience come from the activity of the internal organs. The others are at least less important.

In any discussion of this theory a sharp line must be drawn between the condition of an emotion and its qualities. James assumes the movements and raises no questions as to how they are excited. He takes them for granted as fundamental reactions of the nervous system. He is con-

tent in his detailed discussion to show that the emotion as we feel it is nothing more than the awareness of the bodily state; he makes no attempt to say what causes the reaction itself. He asks only whether anything other than the movements can contribute to the emotional experience. Granting that this in the main must be answered in the affirmative, much further investigation remains ahead of us.

It is to be noted in James' discussion that he does not specify with great accuracy what the movements in any particular emotion may be. He is content to assert that there are movements, and to prove that these constitute the quality of the emotion. In this most of his disciples have followed him. They speak much of strains, sinking feelings, and the like, but no single emotion is distinctly described and distinguished from others on the basis of its bodily accompaniments. For attempts at these details one must turn to recent investigations in physiology.

## Bodily Responses in Emotion

**The Sympathetic System in Emotion.** — Cannon[1] and his students and Sherrington have made experiments which show what some of the changes are and what part they play in the emotion. Cannon asked two questions: 1. What are the bodily responses in fear, anger, and general excitement? and 2. What is the value of these responses to the organism? For an answer to the first question he looked to demonstrable organic responses. In general, emotions were found to spread through the sympathetic system to practically all of the abdominal organs. Pawlow had shown that the flow of saliva and the secretion of the digestive fluids in the stomach were

[1] Bodily Changes in Pain, Hunger, Fear, and Rage.

increased by the taste or odor of pleasant foods, even by sights or sounds that had been associated with such foods. It has also been shown that pain or the emotions excited in a dog by the sight of a cat or in a cat by the attempted attack of a dog served to check the flow of these secretions even when food was taken into the mouth. These emotions also inhibited the movements of the alimentary canal which usually serve to force the food through it. Some of the effects may be seen in man, in whom vomiting reflexes are caused at times by exceptionally strong emotions, particularly by sorrow and fear, not to mention the slighter reactions always present in disgust.

**The Adrenal Glands in Emotion.**—Cannon's experiments prove definitely the importance of the emotion upon the secretions of the adrenal glands, small glands above the kidneys. It has been shown that this gland is called into activity by stimulation of the splanchnic nerve, a nerve of the sympathetic system. The gland was also shown to be excited in most of the violent emotions, by pain, anger, fear, and by general excitement. The effects of this secretion are widespread. Briefly enumerated, it serves first to contract the small blood vessels and to increase the ease with which the blood will clot. This action may be illustrated by the use made of it by the physicians in applying *adrenalin,* the substance obtained from the adrenal glands of animals, to stop superficial bleeding. A second action of the glands is to increase the amount of glycogen, or so-called blood sugar, in the circulation. This seems to be due to the action of the adrenal secretion upon the liver, causing it to release its stores of glycogen and pour them into the blood whence they are carried to the parts of the body that may need them. A secondary consequence of these actions is that the effects of fatigue are checked for a time, and the

muscles respond with renewed strength. This is due in part to the fact that the constriction of the blood vessels increases the blood pressure, and so more thoroughly and quickly washes out the poisonous products of earlier action; and in part to the fact that the glycogen furnishes a quickly assimilated food to the muscle. It could be demonstrated that stimulation of the adrenal glands produced each of these effects, the blood vessels were contracted, the blood pressure increased in consequence, the composition of the blood was changed so that it coagulated more easily, the liver was stimulated to secrete its sugar and, as a result, fatigued muscles were temporarily increased in strength.

These same effects were all produced by pain or strong emotion, provided the adrenal glands were present and connected with the sympathetic system. The increase of blood pressure in emotion is well known, and experiments showed that the blood would coagulate more quickly after strong emotion. The increase in the sugar in the blood was demonstrated in cats subjected to pain, or which had been frightened by dogs when no injury could be done them. The same effect is exerted in man. It was found that of twenty-five players on a Harvard football squad twelve had increased secretion of glycogen, as shown by sugar in the urine, after the contest was over. That this condition was in part due to emotion was shown by the fact that five of the twelve were substitutes who took no part in the game and that the only excited spectator examined also showed the same reaction. Students examined before and after a difficult and important examination showed presence of glycogen after, but not before, the test.

Looking at the phenomenon as a whole, one may readily see the utility of these reactions in emotions. The strong emotions, particularly the unpleasant emotions, are in

animals, and were in primitive man, very likely to be followed by a fight or other violent effort. The animal subject to emotion must usually either fight or run. The bodily changes are a preparation for this effort. The contraction of the blood vessels in the abdomen forces blood into the peripheral vessels and the respiratory tracts, preparing them for greater effort at the expense of the digestive tract, which temporarily ceases its function. The increased glycogen and more rapid circulation under excitement supplies nourishment to the muscles and removes the products of fatigue, thus making them capable of greater activity. The constriction of the arteries and quicker clotting of the blood serve to diminish the hemorrhage in case wounds are received in the conflict. All together, emotion increases the energy of the individual and lessens the liability to injury. It is said in this connection that an artificially induced anger has been used by some individuals to spur them to greater effort.

**Identical Reactions for All Emotions.** — Cannon concludes from his experiments that all the activities he has studied show the same characteristics for all vigorous emotions, whether pleasant or unpleasant, whether relatively passive as fear or active as anger. All this, then, must be regarded as having a tendency to disprove the extreme form of the motor theory of emotion, and even to narrow the applicability of the statement that the characteristic qualities of emotion are dependent exclusively upon the bodily response. This theory was also seriously questioned by Sherrington as a result of experiments upon dogs in whom the connection between body and head had been destroyed by sectioning the upper part of the cord. After the operation they showed the same emotional response as before, had the same emotions as inferred from the reactions

of the muscles of the head. It was objected that associations may have been formed between the stimulus to the emotion and the expression of the muscles of the head by the intermediation of the bodily responses, and that these connections remained after the sensations from bodily responses had been cut off. This objection was obviated by repeating the experiments on puppies only three weeks old who had had no chance to form this indirect association. The results in this case were the same as before. Sherrington is convinced that the emotion is the result of cerebral rather than of somatic reactions.

**Is Emotional Quality Due to Bodily Response?** — If we accept the results of Cannon and Sherrington, it is evidently necessary to ask how much we can retain of the James theory. What Cannon's experiments prove is that there is a large background of physiological reaction and probably a large mass of sensations, common to emotions of all types. In psychological terms one can say that all emotion produces an excitement, and that this excitement has a common quality no matter what the occasion. In this, emotion is not unlike affection, in which it was found necessary to give up the old statements that the physiological responses for pleasure and pain were opposed. We know that both excite the same changes in circulation, secretion of tears, and of saliva. To this now we may add that they cause the same secretions of adrenalin and the same diminution of the reflexes of the alimentary canal, and that emotions differently aroused are also not to be distinguished in their fundamental physiological effects. The possibility remains that on top of these common elements there may be other responses sufficiently distinctive to constitute the peculiar qualities of the different emotions. An answer to this question requires more detailed investigation than has

been given it, for in spite of the long controversy over the James theory, relatively few accurate and extended observations have been recorded of the sensations that come with the emotions.

**The Distinguishing Responses of the Emotions.** — If we may attempt to supply the lack of accurate study by making use of chance observation, statements of novelists, psychologists, and acquaintances, it seems that facial expression, the bodily posture, and a few very general feelings offer the most striking means of differentiation. There are characteristic differences between the facial expression in grief and in joy. In the one the lines of the face are mostly concave downwards, in the other concave upwards. The bodily posture is also different, drooping and contracted in grief, erect and expansive in joy. Of the more internal processes the most evident seem to be an elation in joy and a depression with grief. One gives a lightness that seems to be localized in the chest, the other a heaviness with its seat in chest or abdomen. No one of these subjective processes has been referred to a definite bodily organ. Strains from the head may be added, but, after all, the list of bodily feelings that can be clearly distinguished is extremely short. Of the specific emotions fear may be distinguished from anger by the general weakness and relaxation of the one and the general consciousness of strength and the accompanying activity of the other. Disgust may include sensations of incipient movements of rejection of food either from the mouth or œsophagus. Wonder, to complete Shand's list of primary emotions, involves relatively slight sensations of strain from the wide open eyes or slightly open mouth, together with the quiescence that comes from the cessation of movement. That these are part only of the movements or sensations involved

in any of the emotions considered is at once apparent. That the facial expression and bodily posture are not sufficient in themselves to account for the awareness of emotion is evident from James' evidence that an actor might act a part and not feel the emotion. Careful investigation may be able to go much farther in discovering the movements essential to each emotion. For the present we may content ourselves with the statement that on a background of common responses which furnished the excitement — an element in each emotion — other reactions occur which possibly are characteristic of each emotion.

**The Origin of Emotional Responses.** — For the simpler emotions the nature of their responses can be explained at once as due to the original instinct. As McDougall and others before him put it, the emotion is merely the conscious side of the instinct. When one runs away the observer sees the running with its accompanying pallor and calls it the instinct of flight, while the runner has the emotion of fear. McDougall parallels each of his instincts with an emotion. Disgust accompanies repulsion; wonder, curiosity; anger, pugnacity; elation, self-assertion, in the same way that fear accompanies flight. Watson has suggested more recently that emotion is the innately determined response of the autonomic nervous system, while instinct is the innately determined response of the central nervous system. One would involve the reaction of glands and unstriped muscles, the other of skeletal or striped muscles. The difference between the two is largely as to whether emotions involve other than the unstriped muscles. In the main, emotions are marked by the internal autonomic responses. There are exceptions, however, which destroy the complete adequacy of the definition.

On either theory the explanation of instinct in and of

itself is an explanation of emotion. This holds of the larger, more useful responses, but many of the subtler movements are now merely expressive. Even these can be explained directly as the remnants of responses once useful to the preservation of the organism which in many cases have ceased to be useful. They arose as did all instinct by virtue of the survival of the organisms that developed the responses, or by the dying out of organisms that failed to develop them. A large number of the movements can be shown to be direct survivals of such instinctive responses. Running away, drawing back, or the start of fear, evidently removes the individual from the neighborhood of the dangerous object. Less obvious is the utility of the trembling and loss of strength that come momentarily in fear. This may be traced to a reduced form of 'playing possum' or of crouching and remaining motionless as seen in the rabbit and other defenceless animals. It forces them to remain motionless and thus enables them to escape the attention of pursuers and possible enemies. The cry of the child is similarly useful in attracting attention when it is alone or is uncomfortable. In each of these cases, the conscious state, the emotion proper, is probably of slight value but seems to be an unavoidable accompaniment.

### General Aspects of Emotion

**Theory of Transfer of Emotional Expression.**— Darwin has suggested that three other classes of emotional expression must be recognized which serve still farther to explain or at least to classify the development of emotional responses. These are first, that when an emotion or a condition has given rise to one form of expression, a similar emotion or situation will give rise to a similar response. The second is that, granted an original response, an opposed

situation will give rise to the opposite response. His third class is that in which certain emotions result from the direct overflow of nervous excitation without any controlling conditions. The first of these laws is illustrated by the sneer, which Darwin refers to the snarl of the dog. The dog when a possible enemy approaches exposes the teeth and prepares for an attack. In man the situation is similar and probably the mental attitude also. In consequence man, too, draws back the corners of the mouth, although there is now no thought of biting. Similarly, in anger, the nostrils are frequently slightly expanded, although there is now no particular utility in the movement. This Darwin would explain as preparation in the animal for admitting air while the mouth was stopped with the hairy body of the antagonist. The expression continues although the original occasion no longer exists. The second class is more open to objection. The best illustrations are furnished by the movements of a cat in expressing friendliness. When angry the cat crouches, keeps the ears back where they will not be in danger of injury; the tail is down and lashing the sides. When pleased, the opposite of this position is taken. She is erect and arches the back, the tail is held high, ears erect. There is no particular reason for this group of responses, and Darwin finds it in the law of antagonism. The mechanism that leads to this opposed reaction is altogether unknown, and, as we have seen in connection with the feelings and in the recent studies of emotional expression, there is no evidence of a tendency to opposition in the expressions. The third class, of direct overflow, includes all that cannot be explained under the other heads. Of course it is not really a new head, as all are due to direct overflow of nervous energy, and this third class includes only such forms of expression as cannot be accounted for at all. Darwin's

instances are not very well authenticated. One was of an individual whose hair turned gray over night when he was condemned to die in the morning; the report being based on the statement from hearsay of a British Indian officer.

**Emotion and Language.** — Certain of the emotional accompaniments, in fact many of those that come from the more external and voluntary processes, have taken on a secondary value as a means of communication, as a means of indicating to another the state of one's mind. The facial expressions directly convey an impression of the emotion and serve as warning or encouragement to the companions to cease or to continue the line of action that they happen to be pursuing at the moment. It is probable that the beginnings of articulate speech are to be found in emotional expression. Many of the lower animals express emotions through sounds, and it seems possible, even probable, that speech came from the association, of some general attitude of the individual making the sound, with the sound; and that little by little other associations came to be made with it until our present fully developed languages made their appearance. We can still determine the emotional tone from the modulations of the voice. The loud tones and marked accents of anger, the dragging monotony of the whine of discontent, the softly modulated tones of affection show the emotional state very much more clearly than can any explicit statement in words. They can be detected easily in speech even in a language that we do not at all understand, and convey almost as much of the emotional attitude of the speaker in an unknown language as do words in our own tongue. It is not impossible that these varying cadences were the primary forms of expression and communication and that the words as they developed have been fitted into them.

**Emotional Reaction to New Situations.** — In the emotions of our second class, due to thwarting or furthering of acquired purposes, the explanation of why the movements should be aroused is not so direct. As was said, the bodily reaction, if one judge from immediate consciousness, is the same as in the other group. Instead, however, of having as the occasion for the reaction some stimulus that has an inherited connection with it, it is aroused by an idea or event that must have become associated with it through experience. Thus, anger or sorrow over the loss of a social honor cannot be said to have a definitely instinctive origin, but the bodily reaction may be little different from that excited by loss of a dinner and may continue for a much longer time and with greater intensity. Part of this transfer of emotional response from immediately instinctive to more recently developed processes may be explained on the analogy of Darwin's laws. A vague similarity between the more complex and the simpler situation leads to the arousal of the same instinctive responses for both. The social honor is a prize which through the effect of life in the community has become as desirable as a bit of food. When it is lost, the reaction is the same as that which follows the loss of something whose appeal is instinctive. Whatever the mechanism, certain it is that the interrelations of acquired tendencies and their interaction with the environment do lead to responses identical with the purely instinctive.

One may add to these the assumption of Dewey that much of the quality of emotions may be due to conflict or coöperation between the habitual responses. These acquired responses might stand to the instinctive responses as the acquired ideals and needs to the innate or instinctive. Possibly the interaction of systems of experience or of neurones might give rise immediately to a conscious quality.

If one were to take the result of Sherrington's experiments at full value it would be necessary to assume some such effects and qualities of purely central interactions. Two loopholes in his argument make this conclusion doubtful. His experiments left his pups with a connection between the cortex and the facial muscles, so that the latter might give rise to the emotional content. Secondly, his only evidence of emotion was the facial expression. Really all that his experiments prove is that one may have the facial expression of an emotion without any connection between the cortex and the trunk or limbs. While much work remains to be done toward relating particular emotions to bodily responses, there is every reason to believe that the quality of the emotion, whether it be immediately instinctive in origin or arise from interrelations of purposes and acquired ends, is due in large part to reflex activities. Most of the response is common to all sorts of emotion, but added qualities probably give much of the distinctive tone to the separate emotions.

**The Kinds of Emotion.** — While the quality of emotion may be accepted as in large part determined by the bodily resonance, the names are not given to emotions on the basis of these qualities. This may be due in part to the large mass of sensations common to all emotions and in part to the fact that emotions are usually named, if named at all, after they have ceased to act, or by an observer. During the emotion one is too much interested in other things to consider its qualities. In consequence names are usually given on the criteria of the causes of the emotion or of its outcome. Perhaps, too, the fact that fear and anger, love and jealousy, and other emotions are so nearly indistinguishable is to be found partly in the fact that one changes into another with great rapidity. Anger is dis-

tinct from fear only in the consciousness of power or weakness toward the intruding man or object, and this changes from moment to moment as the situation is faced. One first fears, then becomes angry, and again is afraid, as long as one is living through the experience. When the situation is properly classified, when it is settled that one is stronger and must fight, or is weaker and must run, the emotion is said to take on a new phase, perhaps even to disappear. If one assume a changing response or perhaps a conflict of responses during the emotional state, it is no wonder that the physical accompaniments of opposed emotions should be identical. Both physically and mentally the two fuse, and one may not be sure, even after the event, whether fear or anger was dominant. This rapid alternation of expressions, taken together with the fact that there are always identical responses in the sympathetic or autonomic system, makes classification difficult in practice, and then largely in terms of the intellectual antecedents, the nature of the object, and the outcome of the adventure. It is this that led the popular mind and earlier philosophers to the classification of emotions in other than motor terms.

**Relation of Emotion to Other Mental Processes.** — Emotions have many and close relations with the other mental processes. In many cases we can trace the development of emotions to the association of ideas. The occasion for the emotion is not infrequently to be found in a recalled event. The reaction in this case is usually not so strong as that made to the original event or sensation, but has many of its characteristic qualities. Often it seems that there is an association between emotional states themselves. After some pleasant emotion the liability to painful response is decreased, while after a disagreeable one, all

may tend to produce a disagreeable emotion. After one success has produced elation every event assumes a roseate hue, — one is easily pleased, the emotion of joy comes of itself. After failure, doubt assails with each new venture. Similarly, after one fright, fear is easily aroused. In short, any intense emotion leaves a predisposition to the same or similar emotions.

Emotion has so many similarities to feeling that it is difficult to draw the line between them. Almost all emotions are affectively toned. The sole exception is to be found in surprise. The differences between feeling and emotion are largely in degree. The affective tone is usually stronger in emotion. As the name implies, the motor responses are more striking and more fully developed. It is generally true, too, that the cause or occasion for the emotion is to be found on the perceptual level, in a stimulus as appreciated, rather than in the bare sensation. No one of these distinctions can be applied without exception, but all taken together, now one, now another predominating, serve to draw a distinction in practice.

In their relations to voluntary acts emotions have opposed effects, dependent probably upon whether we consider one or the other type of emotions. In those which have an ideational occasion and are to be regarded as interferences with the acquired ends of the individual, the effect of emotion is generally to increase the motor efficiency, at least in the coarser acts. The more primitive emotion, the subjective accompaniment of an intense instinctive response to an external stimulus, is more likely to inhibit voluntary movements, particularly the more refined and accurate movements, although even here the actual strength is increased and the individual is probably

more efficient in a fight or in flight. Numerous exceptions may be found to both rules and exceptions. Fear or even anger may leave one practically helpless, with a tremor or weakness that prevents all movement for a time and then probably increases the capacity. Again, slight emotion may enable one to carry through relatively delicate activities, those of an artistic character, for example, that one might not be capable of in a calm moment.

**Emotional Control.** — One may control emotions in some degree. The only real control is that effected at the source. The nature and degree of an emotion depend very largely upon the way a situation is classified. An event frequently may be referred to more than one head and will arouse a different emotion under each of these classifications. A human brain, presented to a class with numerous references to what the individual must have thought with it, and with other remarks that emphasize the personal side, is very likely to arouse intense emotions; but, if considered only in connection with tracts and structure, may excite mere scientific interest. Many of the events of everyday life show the same phenomenon. Classify a remark or the man who makes a remark in one way and you become angry; regard it or him in another light and you are only mildly amused. Much also may be done by preventing expression, although this too can be controlled only by changing the attitude or in directing attention to something else until the occasion for the emotion is past. Either method of control becomes much more effective after practice. Like everything else, attitude and response become habitual; instinctive reactions are changed by habit. The physician or surgeon can look upon patients as cases and neglect the more personal relations. Such professional attitudes are taken by members of nearly all

professions with the corresponding development or suppression of emotion and emotional expression.

**Possible Injuries from Control.** — The control of emotion has taken on new importance with recent advances in the study of the causes of nervous and mental disease. Many of these are closely related to the emotions. According to the Freudian school, all but the diseases directly connected with diseased tissues are to be explained as the result of conflicts between opposing emotions or from the checking of emotional expression by social pressure. Repressing an emotion has as its consequence the dissociation of that experience from the general consciousness, and the repression of the experience into the unconscious which may result in hysteria, with its train of paralyses, anæsthesias, and other defects, or even in the insanities of the dementia precox group. The extreme advocates of the theory argue that instincts and the emotions that result from them should be given free rein, that any interference might result in a disease or in increasing the liability to disease. Taken in the broadest sense this would be subversive of all discipline and would probably be worse for society than the presence of a few hysterics or even insane. On the other hand constant and unnecessary repression of all instincts, such as is seen in families dominated by a too solicitous mother or overbearing father, can be avoided without any serious social consequences, and may save the mental health of the child. The motto should be free vent for instincts wherever there is not too much injury to others, with discipline restricted to essentials and exercised with as much consideration as possible. Where repression is necessary it should be made to take, as far as possible, the form of a transformation to some other object than that usually given it. Control by

changing the classification of the stimulus is also relatively harmless.

**Conclusions Concerning Emotion.** — We may think of emotion, then, as a disturbance of the usual or normal course of any succession of thoughts or activities by the intrusion of a new or extraneous event. This event results in a more or less prolonged disturbance of the activities, accompanied by many useless and incoördinated responses, and by intense affection. It is possible to distinguish two types of emotion, or at least two extremes of emotion. One, usually the more violent but usually of short duration, is directly dependent upon instinct, both in condition and response. This is the type that may be defined as the mental accompaniment of an instinct. The second type, which is usually of slighter intensity and greater duration, is conditioned by the thwarting or furthering of the system of purposes developed by the individual upon an instinctive basis. Even for this class the responses are also of instinctive origin. In this latter case, however, we must look to the mental antecedents rather than to the physical responses as the cause of the emotion, and as the determinant of the type of emotion that shall be induced by the stimulus. The bodily reverberation depends upon the antecedent mental states rather than being itself a first cause and constituting, through the sensations it excites, the entire emotion. This is not to deny importance to the movements in giving color to emotion; it merely insists that other factors must be considered in discussing its origin.

## Other Mental States Related to Emotion

**Sentiment.** — Sentiment is ordinarily used to designate the milder, more lasting forms of emotion. Shand has

varied the application of the term to indicate the antecedent condition of emotions, the system of impulses that dominates the individual, which, when furthered or hindered, gives rise to the emotion. The sentiments are for him dependent upon the instincts, but the instincts are in turn modified and developed by experience. The two great systems are love and hate. These are fundamental, constitute the impelling forces of all activity, and give rise to emotion when acted upon by particular events. When aroused they are or may be directed toward particular persons or objects. They approach the particular emotion rather than the fundamental tendencies which constitute the impelling force needed for the development of emotion. This definition emphasizes the characteristic of duration implied in the usual meaning of the word, and has been accepted by McDougall and Stout. There is no doubt that a name is needed which shall designate the systems of impulses or purposes. However, some word implying greater force would be better than sentiment, since these systems are the forces behind all voluntary activities, mental and physical, as well as the occasions for the emotions. What is designated is more like what is usually called desire or a system of desires than sentiment. While the authority behind this definition of the word entitles it to respect, sentiment seems better suited to designate the mild continued emotion, its more usual meaning.

**Mood and Passion.** — Mood is a predisposition to an emotion of comparatively short duration. It may be due to physical causes. Lack of sleep, a fit of indigestion, and many other indispositions predispose to unpleasant emotions, while good health and rest conduce to pleasant emotions or sentiments. Moods, too, develop from earlier emotions. A disagreeable emotion, as was said above,

leaves a tendency to other unpleasant emotions, and this is a mood. Moods, then, are rather dispositions to emotions than any particular kind of consciousness or behavior of themselves. Passion, like sentiment, has been used in various ways at different times and by different men, now being extended to cover the entire field of pleasant and unpleasant acts or mental states, and again restricted to the more violent exhibitions of the emotional reaction. At present it can hardly be said to have any technical meaning. As in the popular sense, it most frequently designates the more violent forms of emotion.

**Temperament.** — Temperament is a word with a long pedigree in psychological usage and one that has undergone little change in application since first introduced. Galen recognized four humors in the body, blood, phlegm, black bile, and yellow bile, and assumed that the disposition of the individual was largely determined by the one that was dominant. These gave rise respectively to four principal temperaments, the sanguine, the phlegmatic, the melancholic, and the choleric. These names still persist, although they have taken on slightly different forms at the hands of different psychologists and in the popular mind. Thus Wundt makes the temperaments depend upon combinations of rate and strength of response in a given individual. The sanguine is said to be quick and weak, the choleric, quick and strong, the melancholic, slow and strong, the phlegmatic, slow and weak. This corresponds to certain of the characteristics of the terms as popularly used, but omits what seems the most important, the tendency to pleasant or to unpleasant emotions. On the whole, the schematism of Wundt has little to recommend it over the looser applications of the term in popular speech. All together it can hardly be said that we know more about tem-

peraments than that individuals differ in their susceptibility to the different emotions. At present there is no complete classification of these dispositions. The ideal of Galen, that one might group individuals in such a way that it would be possible to determine what mental and physical capacities and dispositions were necessarily associated and find some simple test that would determine to which of these classes each individual belonged, is almost as remote to-day as it was when Galen wrote.

**The Ductless Glands in Relation to Mood and Temperament.** — A very suggestive recent theory would relate temperament and mood to the dominant action of various glands of internal secretion, the endocrine or ductless glands. We have seen that the adrenal glands are supposed to be an effective factor in the excitation of the emotions. The other ductless glands may by their secretions prepare the way for emotional outbursts or for the restraint of the emotions. Those most frequently mentioned are the thyroids, the pituitary, and on less definite evidence the thymus. It is assured, for example, that excess of thyroid secretion, as in Graves' disease, renders the subject much more excitable and more responsive to both pleasant and unpleasant emotions. Lack of the normal amount of secretion decreases intelligence. The posterior part of the pituitary body, a gland on the anterior side of the mid-brain, secretes a fluid into the blood which has a tendency to increase contraction of the involuntary muscles. Less well based is the suggestion that the thymus if active for too long in the life of the individual induces the persistence of a childish disposition. The various secretions act through the blood either on the nervous or muscular tissue to produce these effects. This modern theory would replace Galen's humors by the names of these duct-

less glands. If accepted we would have the thyroid temperament, the pituitary temperament, the thymus temperament, etc. It is undoubtedly an advance on Galen, and promises much for the future.

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# CHAPTER XVII

# THE GENERAL PRINCIPLES OF ACTION AND THE WILL

## Action

The final outcome of all thought, of all mental processes whatsoever, is action. In connection with the nervous system it was seen that all stimulations tend to find an outlet through the motor nerves and muscles. Movements play an important part in almost all mental states. Movements accompany all acts of attending, and several authorities explain the fact of attention itself by the movements called out, rather than by the antecedent mental states. In perception, movements are used as a means of explaining space, time, and rhythm; recognition is, for some authorities, merely a revival of old movements. We find many writers who explain many if not all of the essentials of the reasoning processes in terms of movement. Either as beginning, intermediate stage, or end, of every mental state, we find that action has an important place in fact or theory.

We may assume in our present chapter that action is the real aim of life, and that most of the operations so far discussed are preliminary to it. This action may follow immediately upon them, or may be delayed for a considerable period. Here, however, we are more concerned to see how the other processes lead to action, than to understand how the movements may explain them. In the first place, we may assert with some confidence, on the basis

of practically universal agreement of psychologists of to-day, that there are no new forces, nor even any absolutely new laws involved in the control of action. All mental states give rise to movements of greater or less extent; and, on the other hand, movement as a psychological process can be explained only in terms of certain mental states already discussed. Were we to give a complete explanation of movement, we should have a review of each of the preceding chapters, with an appendix on the way in which movement resulted from the process discussed in it. We can at most add the appendix matter in this chapter. Assuming that the fundamental principle of action is that all excitations tend to pass over from the sensory to the motor neurones, we may raise several fundamental questions in connection with this process which may be discussed or put aside now before we proceed to the details.

**Sensation and Movement.** — One of the most important is whether the sensory excitation that leads to movement must be accompanied by sensation. The evident answer is that sensation may or may not accompany the process. Some assert that normally all movement comes from sensation, but we have also the opposite view that all sensation is aroused by the excitation of the motor neurone or even by the movement itself. Neither of these extreme views need concern us here. We may be content with the statement that the excitation of motor processes certainly often takes place with no accompanying sensation, and that all that is really necessary for the movement is the previous excitation of some sensory organ or sensory neurone. This latter may come through some indirect path involving a memory, or the cortical cells ordinarily active in memory. The natural thing is for the sensory process to discharge into movement. What really needs

explanation is why at times the sensory excitations do not cause movements. In the complete sense they probably never fail to arouse some response, but it is frequently too slight to be noticed. The fundamental fact of action in general needs no special explanation.

### Learning

**The Methods of Learning.** — Starting with the single assumption that movements always follow upon, and are

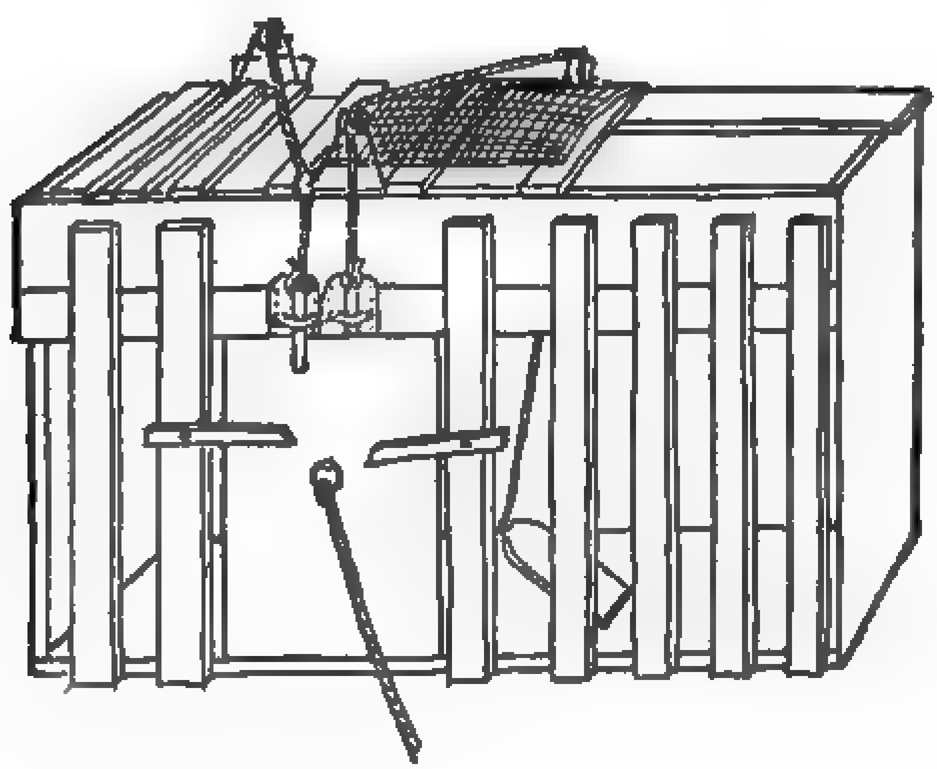

Fig. 94. — Animal problem box. (From Thorndike, "Animal Intelligence.")

the outcome of sensory stimulations, the first question that confronts us is the discovery of what it is that determines the particular movement which shall follow upon any given stimulation. We have seen that certain connections are present in the organism at birth, the result of the heredity and evolution of the individual and of the species, and that learning by trial and error controlled by

instinct supplies the remainder. We may here give a more detailed account of the process of learning.

The experiments upon animals were begun by Thorndike, who tested the methods by which a cat learned to escape from a box that had a door fastened by a simple catch, a button that could be turned, or a bolt that might be drawn by pulling a string hanging down inside the box. To make sure that the cat would make an effort, it was hungry when put into the box, and food was in sight on the outside. The process of learning has been found to depend in practically all animals upon the presence of random movements, — is one of trial and error. The cat makes a large number of movements of all sorts, tries to force herself through all promising openings, bites at all projections, scratches, and mews; in fact, she exhausts all the acts, reflex, instinctive, and habitual, that she has at her command. Sooner or later one presents itself that happens to open the door. She scratches at the button and by pure chance turns it. When the door is open she walks out. But one successful movement does not teach her the method of opening the door. When put in again, she goes through a series of random movements a second time, and again will hit upon the correct response by chance. It is only after a number of successes — the number varies with the intelligence of the animal — that the right movement will be begun at once when the animal is put into the box. Each trial will, on the average, require less time than the

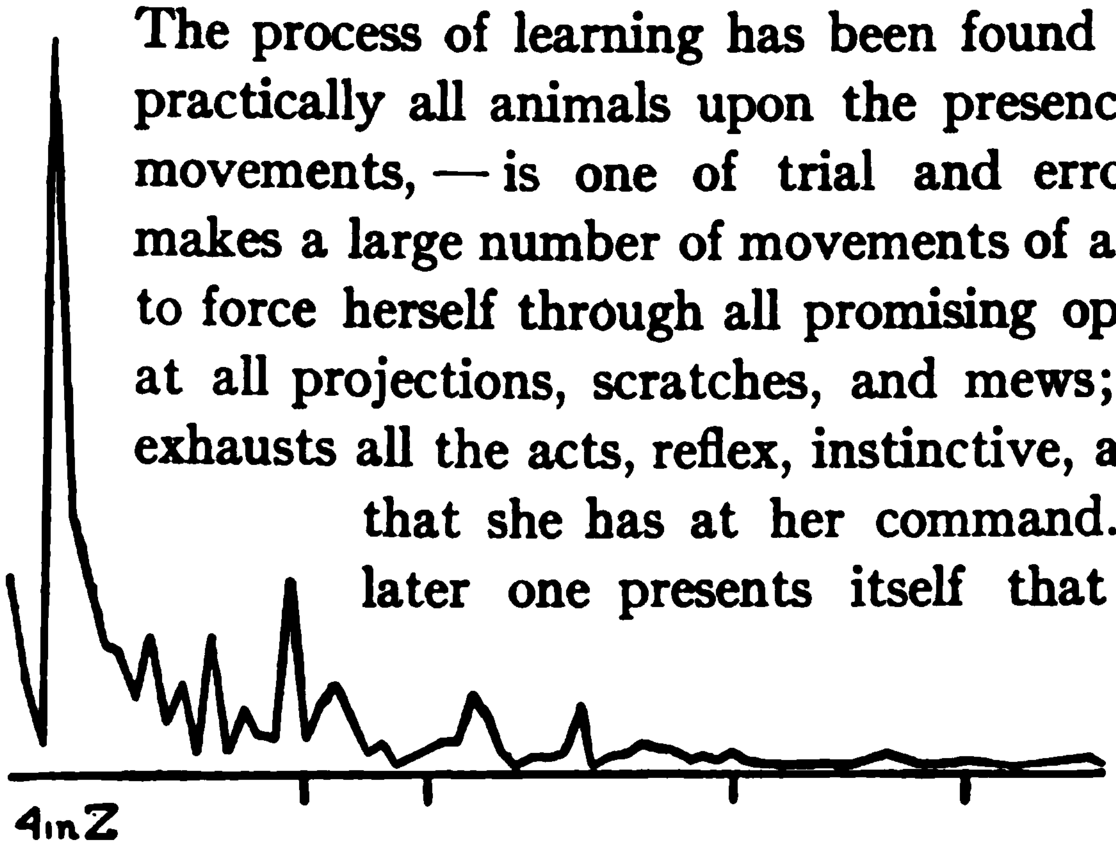

FIG. 95. — Curve of learning in dogs. Height shows time required for hitting upon each correct response. (From Thorndike.)

one that preceded it, but there are many variations owing to chance difficulties.

This process of learning by trial and error governs all of the learning of animals so far experimented upon from the very lowest to man. How low in the scale we may go depends upon what is meant by learning. In the early chapters it was noted that Jennings found that movements were modified by the results of earlier actions even in the unicellular organisms. The Stentor, for example, would, when slightly stimulated, at first bend to one side and then later give up all responses. If the stimuli were made more intense, it would first bend away sharply, and then, after several responses which failed to remove it from the excitation, would release its hold and swim away. This, the most rudimentary form of learning, is nevertheless learning. From that point on, more and more complex movements may be acquired as the organism increases in complexity. The essentials of the learning process in animals seem to be that any problem must be solved by chance at first; that, after the right movements have been hit upon a sufficient number of times, a connection is established between a certain stimulus or group of stimuli and the movement, in such a way that the stimulus tends at once to call out the corresponding movement.

**The Nervous Basis of Learning.** — This still leaves open the question as to what brought the so-called chance response in the first place. If we turn back to the nervous system, it may be said that a given sensory impression stimulates a sensory neurone, which in its turn has axones connected with a number of motor neurones. The synapse to one of the motor neurones probably offers least resistance and the impulse passes across that. If the result which comes from the act gives pain or does not remove the

unpleasant stimulus, a new set of responses will be started as the stimulus becomes strong enough to open less permeable synapses. If, for example, the cat does not escape, get the meat, and in consequence begin the instinctive responses involved in eating, then new synapses will be opened and other movements result until some change in the stimulation starts a new series of responses. It should be remembered that there is not one stimulus but many, and that, as attention changes, new stimuli come which also make possible new movements. When the movement has been made, the same stimulus will produce the same movement, and each repetition reduces the resistance at the synapse as in the formation of association. In animals and in the ordinary learning of man, each movement is the result of instinctive responses or of earlier habits. Watson asserts that there is no real formation of new connections in learning, but that all is due to the elimination of certain of the unnecessary movements in the first trials. His theory is that the inherited connections usually offer roundabout paths between stimulus and movement. This series of responses is innate. Trial and error finally make a more direct connection between the stimulus and the successful act. On this theory learning could never lead to absolutely new connections. It could only shorten the course. Undoubtedly a large part of learning is of this character.

**To What Extent are New Connections Formed in Learning?** — In man, however, there seem to be cases in which there is no natural nervous connection at the synapses, or at least in which the instinctive connection is very weak, and in which learning takes place through a spread of impulses over synapses very slightly permeable. Thus, in learning to move the ears in the experiments that Bair

carried out, a connection was formed, a path of discharge was opened to a muscle not ordinarily under voluntary control. Here there seemed to be a gradual spread of impulse from the usual channels to more and more unusual ones, until finally it chanced to find the old path to the *retrahens* muscle, the muscle that pulls the ear back. Then repetition stamped in the connection until it could be repeated at will. Another case of the formation of new connections is furnished by the surgical operation that replaces an impaired nerve by another with an altogether different central connection. Thus, when there has been paralysis of the nerve innervating the flexor muscle of the arm, it has been possible to divide the nerve supplying the extensor muscle and connect one part of it with the injured flexor muscle. When it has regenerated, the nerves that previously produced extension of the arm now carry the impulses which produce flexion. Here evidently we cannot be dealing with a dropping out of old connections but must have the formation of altogether new ones. Even more convincing are the experiments and treatments of Lasher and Franz. They showed that a monkey which had had an arm paralyzed by extirpation of the controlling area in the cortex would completely recover the use of the arm if forced to use it, although there was no regeneration of tissue. Constant trial induced similar recovery of function in men in cases of long-standing paralysis due to disease. These paralyses must be overcome by the opening of new connections between sensory and motor neurones by the process of trial and error. All three instances involve formation of connections that are not definitely present at birth; in the second instance, in fact, they follow paths and produce movements the reverse of those that are innate. Indeed, much evidence is accumulating that there

is considerable variation in the paths followed during the same function of the cortex. If confirmed, this fact would prove that the formation of new connections is the rule rather than the exception.

**The Acquisition of Skill.** — In the adult man the most important practical problem of learning is how series of acts, already under control in isolation, may be united into a single series, and made to constitute a unitary group. This is what happens when one acquires skill in any game or occupation. A number of investigations have been carried out on problems of this sort. Bryan and Harter[1] investigated the learning of the telegraphic language; Swift studied typewriting, tossing balls, and learning Russian; Bair and Book investigated typewriting. All obtained the same general result, that skill comes rapidly at first and then more slowly, and that in the course of the work there are many periods in which no progress is made, followed by periods of rapid improvement. In each of these tasks the individual movements are known in advance. One can press the key of a telegraph instrument or of the typewriter or toss a ball at the start. What is necessary is to organize the whole so that one element shall start the next, and all shall be carried on together without false movements, and as rapidly as is possible. All agree that improvement here, like the original learning, comes largely by chance successes. One hits upon some more effective combination of movements without any definite foresight, and even without knowing what it was that caused the improvement. The worker does his best all along, and at

[1] Bryan and Harter, Studies on the Telegraphic Language, Psychological Review, 1897, p. 27.

Swift, Acquisition of Skill in Typewriting, Psychological Bulletin, Vol. 1, p. 295.

times an improvement comes, at times it does not. There is always fluctuation from day to day. This seems due in

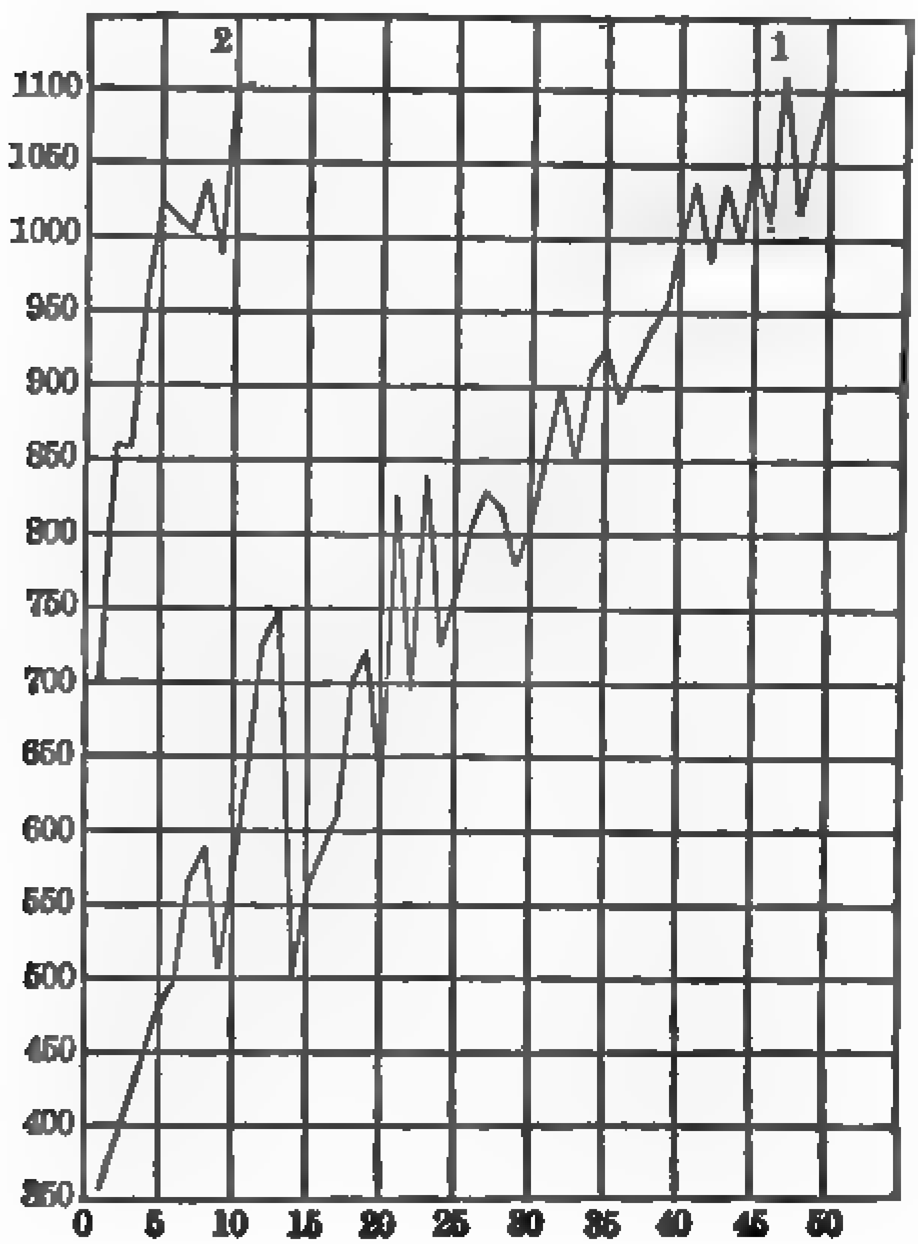


FIG. 96.—Curve of learning to write on the typewriter. The horizontal distances show the number of days of practice; the vertical, the number of words written in an hour. Curve 1 shows the progress during the original practice; curve 2, the results of nine days' practice after an interval of two years and thirty-five days. (From Swift.)

part to the general physical condition, in part to chance changes in the character of the work. The preliminary

feeling offers little or no indication of what the course of the work is to be. One may feel well, even feel certain that a good score is to be made on a certain day, and find that the accomplishment is lower than on days when the general feeling seems to offer less hope of success.

**Plateaus in Learning.** — One of the most interesting questions is why there should be the long periods of no progress, the so-called plateaus. They have been reported by all observers and are present in most of the curves. The same amount of effort is made, and all the conditions seem to be approximately the same, but no progress results for a long interval. Various explanations are given for them. Bryan and Harter assert that they are periods in which the old associations or partial habits are being more firmly implanted, and that this is essential for any farther advance. In certain cases this seems true. It has also been asserted that they are periods in which the worker loses interest and relaxes effort, but most workers do not accept this as a general explanation. They are also found when effort is kept at a maximum. Assuming that the plateaus are necessary as preparation for a new advance, the reason for the rise to a new level offers difficulties. Three explanations have been suggested. (1) The simplest is that the preparation has been completed and then some new combination of movements is hit upon that makes the progress possible. (2) Even Bryan, who argues that a plateau is a period of preparation for increased efficiency, insists that there is often at least some special stimulus. He quotes instances of telegraphers who have spent some time in a small office who show a sudden rise in ability when transferred to a main line office. Here increase is probably the result of new incentives. (3) A third important factor lies in becoming clearly aware of the conditions of the prob-

lem, of what must be done to gain full control, — with this there is frequently an increase of skill. Effort may be helpful, or may not, according to the time at which it is exerted. If all is ready, increased effort may give increased effectiveness; if the effort comes too soon, it may be a detriment and even lead to postponement of the advance.

Batson[1] carried out an investigation of the learning process for tossing balls. His conclusion is that the plateaus are the expression of the time taken to associate several movements into a chain, when the separate movements must be combined into a unit before new progress is possible. Thus, keeping two balls in the air with one hand requires three separate acts, estimation of direction, estimation of the right height to throw the balls or of the force, and estimation of the time required for the balls to rise and fall, since the ball is seen only at its highest point. Unless these three acts could be made together, no real progress was possible. The plateaus were thought to correspond to the periods during which the three factors were being combined, or during which each was being learned separately before they could be combined. If the act to be learned was simple, involving only one process, no plateaus were found. If attention was distributed over the entire process, if all three part processes were attended to at all times, the plateaus were not so likely to appear. In Batson's experiments they were found only in composite acts where the parts were attended to separately and then joined into groups. Whether this explanation will hold for all problems can be determined only when others have been analyzed into their parts in a similar way. We may content ourselves here with the statement that acquiring skill in com-

[1] Batson, Acquisition of Skill. Monograph Supplement, Psychological Review, Vol. XXI, 1916.

plex acts is, like learning in the simpler forms, due to chance trial and error, a process in which the learner does not know how he makes advances either before or after they are made. The associations are formed through frequent repetition, and the plateaus, or stages of no progress, are periods when associations necessary to new progress are being formed. The rise comes through some new accidental combination, due to some new incentive, to an understanding of the conditions of the advance, or merely to the perfection of preliminary connections essential to making new combinations possible.

**Learning by Imitation.** — A suggestion that may deserve a moment's notice is that one may learn by imitation. In one sense this is of course very largely true. We tend to imitate the more striking acts of those in whom we are interested and with whom we come into contact. But at most this acts as a goal toward which one may strive by a process of trial and error, rather than as an immediate cause of the action. That there is no fundamental impulse to imitate is evident from experiments made with animals. Thorndike found that when one cat was permitted to watch another get out of a cage a number of times, the time it required to make the same movements was not noticeably shortened. Similar results have been obtained by various other investigators under approximately the same conditions. In his work, referred to above, Bair found that even compelling the muscle to make the movement to be learned by stimulating it by an induction current did not decrease the time required. The impulse must develop from the cue or stimulus ordinarily used to incite the movement, if learning is to take place. External aid serves at most to direct attention to the right movement; but to make it, if it be not already learned, requires the usual process of

trial and error. The same statement may be made of the effect of imitation in more complex acts that are already at command. The sight of another making them serves to give the idea, and that may, if desired, lead to the act. What force it has is due to the general social instincts, rather than to any specific instinct or impulse to imitate.

## Movement

**Consciousness and Movement.** — When one attempts to determine the factors that precede and control movements already learned, to ask why the movement is made and how it is controlled, one comes upon rather more difference of opinion. We have already seen that all movement follows upon stimulation. These stimulations can be traced in the last analysis to sensory excitation. In most of the more elaborate acts of human adults, some consciousness accompanies this excitation, and in a very large number of cases the excitation that precedes is from the activity of a memory tract rather than from the stimulation of a sense organ directly. Each of these factors introduces certain complications and raises questions that must be discussed. One of the first is, what does consciousness add to the process and is it necessary that consciousness should be present? Here opinions differ. Consciousness does accompany many if not most acts when they are first made. On the other hand, before an act has been definitely learned, consciousness of what is to be done seems, as has been said, to help very little in the learning; after it has been learned, consciousness becomes more and more indefinite until finally it may completely disappear. In view of these facts it seems difficult to do more than insist on the importance of the sensory innervation as universally present. The degree of consciousness and what its effect

upon movement is, may be left an open question; and its presence need be pointed out only where what is conscious gives a definite explanation of the characteristics of the act.

**Initiation of a Movement.** — We may divide the conscious accompaniments of movements into three groups. First, the initiating processes; secondly, the directing sensory processes; third, the awareness of the result. These must be considered separately. What the initiating process may be has been much discussed, and many suggestions have been made concerning it. Probably all have been too definite. Thus, several have inclined to the view that movement must be preceded by the kinæsthetic sensation that arises when the movement is made. To speak a word, one must recall the sensations made when that word has been uttered at some earlier time; or to move the hand to cut the leaf of a book one is reading, one must recall the sensations felt when that movement was made. Woodworth[1] has shown that these sensations are seldom present, and a little observation will indicate that you do not ordinarily have them in mind before the movement is made. Visual images are more frequently present, but even these are not always definite. If you decide to rise and walk across the room, you will see that all that is necessary is to notice a book and remember that you must read something in it before you go on. With a very general idea and the sight of the book, the movement begins and is carried to its conclusion. Even visual images are not always present. This is too obvious to mention in the case of speech, which is influenced more by auditory images. In most cases the imagery that precedes, whose presence may be regarded as constituting the intention to move, is very schematic;

[1] Woodworth: The Cause of a Voluntary Movement. Garman Volume, p. 351.

and almost anything in any way related to the act may serve as the incentive to movement.

**Meaning as an Incentive.** — In this, action is very little different from thought. In fact, Woodworth first came to his hypothesis of imageless thought through a study of the mental content that precedes action. As in thinking, our memories and ideas are brought into systematic groups, in which any one element may serve to represent any other, so the antecedents of acts are also grouped, and the act results from the appearance of any element of the system. Organization is as evident in the control of action as in the control of thought. Just as an idea which is not at all similar to an object may represent that object, so an idea or sensation that has been only indirectly associated with a movement may come to represent that movement and in fact constitute the intention to make it. In practice one finds that almost any idea or impression that has been connected with an act may be the immediate predecessor of that act. Any mental process may constitute the incentive to any act with which it has been closely associated, in the same way that any image may have as its meaning any idea with which it has been associated. Colloquial language connects the two, and uses the single word for both. 'I mean to do that' is a common expression as the equivalent of 'I intend to do that,' and the use of the term is justified by psychological analysis. A meaning, using the term in the technical sense of the earlier chapters, may quite as naturally have an issue in movement as stop short in the mere representation of an idea.

**Different Types of Antecedents of Movements.** — Three distinct classes of mental processes may be discovered among the antecedents of action. (1) The most common is the intention or the meaning, a representation in some

form of the goal or result of the act. This goal may be represented as a concrete sensation, as a very general notion, or may have no appreciable imagery, or at least no appreciated imagery. It may take any of the forms of a concept. The initiating idea for a stroke at golf may be a definite image of the point where the ball is to land, it may be some vague verbal thought that it is well to land near the tree on this hole, or it may be that the stroke is guided by nothing more definite than the assumption that the next stroke is in that general direction, an assumption that is not formulated but is due to the appreciation of a particular step in the game. It must be said that this stage is very rare in a game of skill, but much more frequent in partially automatized tasks. (2) At times, intention is lacking or much in the background, and a sensation or idea closely associated with the movement serves as the incentive. This may be either the kinæsthetic image mentioned above, or it may be the sight of an object, as when a spot on the tablecloth catches the eye, and the finger moves towards it even to the later embarrassment of guest and hostess. The second cue is different from the first in that it does not correspond to a purpose, or may be directly opposed to the general purpose. (3) Finally, some sensory stimulus may cause a movement that is altogether unrelated to the intention of the moment.

*Interaction of Incentives.* — These three different sorts of antecedents may oppose and disturb each other in the control of the resulting movement. The intention is the most frequent antecedent but, if at any point in carrying out the intention an extraneous idea be permitted to become dominant in consciousness, it disturbs or prevents the movement. Thus, if one is making a golf stroke and suddenly permits the ditch immediately in front to catch attention,

the ball goes into the ditch in spite of the good general intentions of the player. In a baseball game, in the same way, if some object other than the point at which the ball should be thrown is attended to, a bad play is fairly certain to result. Even the attachment of a *not* to an idea does not always prevent it from affecting the act. Langfeld[1] found that in experiments which consisted in moving a wire along a groove, endeavoring to avoid touching the sides, the experimenters were more likely to touch the edge if he asked them not to touch it than if he told them to keep the wire in the middle of the groove. Attention to the side induced a movement toward it in spite of the intention to avoid it. Within limits, trying not to do a thing has the same effect as trying to do it. This is particularly true in acts of skill and of movements only partly learned. It is true in general that an intention of the more remote sort is frequently conquered by an idea of a specific movement, even if that be directly contrary to the intention. The same holds of the third type of antecedent, a sensation not directly connected with the movement. A sudden stimulus that comes in the course of an attempt to make a difficult movement will frequently disturb or destroy it. A sudden loud noise or bright light spoils a delicate line with the pen, or the aim of a rifle, or a drive at golf. Not the meaning alone, but that, together with the idea or object that holds attention, or the sensory stimulus that forces its way into consciousness, serves to direct the movement.

**The Control of Movements.** — The sensations aroused by the movement constitute the second of the three groups of conscious states accompanying movement. These sensations serve primarily to direct the act. Movement is

[1] Langfeld, Movement under Positive and Negative Suggestion. Psychological Review, Vol. 20, p. 459.

in this respect much like memory or reasoning or the process of learning. The incentive must be distinguished from the control; the attempt, from the recognition of success or failure, together with the correction that goes with the latter. In addition to the sensory processes that initiate the movement, the accompanying sensations exercise a constant guidance. These are divided by James into two classes, the resident and remote sensations. The resident are the kinæsthetic sensations. The remote are the sensations from eye or ear, that indicate where the moving member is, or what the sound is that is being produced. Both of these sensations or groups of sensations ordinarily control the movement without being directly noticed. As a finger is moved with the eyes closed, the kinæsthetic sensations are constantly coming to the cortex and sending out reflexes which serve properly to direct the movement and to adjust its force and extent. They are most easily demonstrated by their absence. In tabes the motor nerves are unimpaired, but the posterior columns in the cord which carry the kinæsthetic sensations are destroyed. A characteristic symptom of the disease is inability to control movements. When the eyes are closed, the patient is not able to bring thumb and finger together accurately and still less to bring two fingers together in front of the face with a single sweep. Locomotor ataxia with its irregular gait is one form of the disease.

**Remote Sensations.** — The remote sensations are also active in detecting and correcting any departures from the intended course of action. Thus, when writing, if the hand starts to make a crooked line, the deviation is at once seen, and the eye directs the pen back to the right path. The influence of the eye is not appreciated; but, if one attempts to write with the eyes closed, it is at once apparent that an important correcting force is lacking. The ear acts in the

same way in governing speech and the tone in singing. Experiments show that most singers, some of them among the most famous, are not able to strike the correct tone at once, but make an attempt, are quick to detect that the tone is too high or too low, and so adjust the pitch to the correct one. The violinist, too, does not estimate the position of his fingers on the string by the kinæsthetic sensations, an estimation that would require marvellous accuracy, but approximates the position first, and then, as the bow begins to give the tone, he adjusts the length of the string until his ear tells him that the tone is correct. That the remote sensation is essential is shown by the fact that the deaf cannot speak without special training. The training consists in teaching the patient to control the voice by kinæsthetic and tactual sensations instead of by the sounds that are used by the individual who hears. The deaf child feels the teacher's vocal organs, and keeps trying until he makes his own carry out the same movements. The sameness of movement is at first recognized by touch, but with practice the kinæsthetic sensations from the vocal organs suffice. These control processes also become automatic, so that one notices neither the sensations themselves nor the fact that they exercise control. The sensations from the eye guide the hand reflexively, or with as little thought as is required for the reflex.

Another striking case of reflex guidance of this sort is that exerted by the static sense, the stimuli from the vestibular branch of the auditory nerve. This, as was seen in the earlier chapters, makes close connections with the motor centres in the brain stem, particularly with the cerebellum and the roots of the motor oculi nerves. These sensory nerves probably give no sensations, but nevertheless they guide the movements of the body as a whole, serve to

keep the balance, give rise to compensatory eye movements, — movements that keep the eyes fixed on the same point in spite of the movements of the head and body. The sensory impulse calls out these movements continuously and often we have no knowledge that the movement has been made; certainly we have no appreciation of the fact that they produce the movements. The stream of impulses coming in through the vestibular nerves constitutes one of the important forces which control any movement of the trunk.

Any act, then, may be said to be the outcome of the appreciation of a situation that requires movement. The immediate incentive is usually some object or idea that for the moment holds the centre of attention. But this incentive is seldom the picture of the movement to be made; more frequently it is some idea of the end to be accomplished. If the movement is relatively unfamiliar, it is an idea of some immediate act; if very familiar, a more remote end is usually held in mind. The intention does no more than mean the movement; it seldom recalls it in sensory terms. The movement is always guided by the resident and remote sensations. These adjust it to the conditions of the moment. When a movement has been repeated sufficiently often to become automatic, attention is needed only at the beginning. The act is started, and attention then turns to something else; the association between the movements and the resident and remote sensations serves to carry it to its goal. Thus, in walking on a familiar course, one merely decides to go to a certain place and, when once started, one step starts the next, always under the control of the remote and resident sensations. The visual stimuli lead to the avoidance of obstacles and guide in making the necessary turns. Unless some new obstacle is encountered. one may

go into a 'brown study' at the moment of starting and not realize again what is going on about until the destination has been reached. All movements or chains of movements, at first learned or joined together by effort and under the influence of a complete consciousness, tend gradually to lose more and more of the conscious accompaniments and antecedents. Finally, in more complex acts, they may start from some unnoticed stimulus; in the case of simple acts or a number of unified simple movements, they may be started by a single idea, may be initiated by a conscious process and guided to their end by habit without further consciousness. Associations between the movements themselves or between the resident sensations of one movement and the motor processes required for the next, take the place of all more definite awareness. Even in these automatic acts, there is guidance by a wide group of habitual connections between neurones, not at all appreciated by the agent.

## Choice

**Choice and Motives.** — We have been assuming, all through, that the intention to make a movement has been present, but a process antecedent to the intention requires discussion. This is the problem of choice. It is true that most acts are automatic or habitual, that the decision was determined long before the time of performing the act, and, when the occasion presents itself, is carried out immediately. But in some instances two opposed acts are felt to be possible, and it is necessary to choose which is to be made. The actual act of choice is relatively simple. It amounts merely to giving one intention free play and checking the others. The actual mental content consists in attending to the movement to be made or the result to be attained. When the choice or decision is made long be-

fore it is to be carried into effect, it consists frequently in outlining the course of action in words or in some idea, — some concept perhaps. When the time comes, the stimuli present lead at once to the act. The only new problem in connection with choice is as to what leads to the intention, why one course is chosen rather than another. This depends upon the selection of one or the other of the possible ends present to consciousness. The explanation lies finally in the laws of attention and association, and offers little that is new. The deciding factors are the subjective conditions of attention and of association. One seldom regards as choice the decision determined by objective factors alone.

**Mental Attitude in Control of Choice.** — The influence of the situation and the mental setting or context have been frequently mentioned above. It was brought out in a slightly different form by Ach[1] in a long investigation of the conditions of choice by means of the reaction experiment. First he asked his subjects to move the right finger when a letter *E* was shown, and the left when the letter *O* came. The times required for making each movement were measured. It was found that no real decision was made after the cards were shown, but that the movements were made at once because of the previous preparation. This is evident from the fact that more time was required when the subject was left free to react with either finger than when the finger to be moved was prescribed. In the latter case part of the preparation for action had been completed before the movement began. These facts may be regarded as indicating that the first form of reaction gives play to choice, while the others are determined by the conditions of the experiment, the purpose of the moment. It was in

[1] Ach, Ueber die Willenstätigkeit und das Denken.

these same experiments that the control of the arithmetical associations was studied: When two numbers were shown one above the other and the observer was told in advance to add or subtract, the result came at once or after a relatively short time. When, on the other hand, the numbers were shown with no instructions, the resulting process was much delayed, and the observer had a chance to study the process of choice. The task or purpose serves to control choice just as it does to determine association. The effect of the purpose is replaced by the situation and the general intentions of the moment in many choices of everyday life. It is this that leads one to take an umbrella when the sky is cloudy, and a cane when it is clear, as one goes past the rack in the hall; to choose a serious volume when one comes into the study in working hours, and a novel or the newspaper in the period just after dinner. In all these things, the choice, while apparently undetermined, is guided by the general attitude and the environment.

**More Remote Influences in Choice.** — In more complicated and important instances of choice, the final selection is similarly determined, but the controlling influences are much more numerous. The final release comes with thinking of the end to be accomplished with the full belief that the act is to be carried out. The antecedent processes are much like the balancing of decisions in doubt before full belief presents itself. First one alternative is thought of, then another. After these alternations have repeated themselves several times, one finally dominates, is held in mind, and the others are by that very fact excluded; the decision is made. The forces that favor the possible alternatives are to be found in the instincts on the one side and the social forces on the other. They constitute what are called the motives. The motives are themselves ordinarily

quite largely out of consciousness. One knows only that one course of action or another is preferable but has no knowledge why it is preferred. Carrying this back, we see that of the possible lines of conduct the one is chosen which proves most attractive. Why it is attractive is determined by natural endowment and education. There is no trace of what is commonly called will.

## The Will

**Is there a Peculiar Will Element?** — A problem much discussed since the beginning of psychological theory is whether there is a specific quality or a specific function, apart from those outlined above, which can be called the will. The earlier writers, always tending to discover a separate faculty or force for each of the words in common use, hardly questioned the existence of something of the kind, something which was an actual force in decisions and an incentive to action. As the direct examination of mental states began to take the place of speculation with only inaccurate observation, fewer and fewer men were able to discover this peculiar state. Instead, an ever-increasing number of authorities found the final cause of action in an idea that was attended to, in an idea of movement with the belief that it was to take place, or in the feeling qualities preceding or accompanying the idea. As more and more work was done upon the analysis of the consciousness preceding action, the less was there found that was peculiar to this state.

Recent investigators, Ach and Michotte and his followers, have revived the old doctrine in a slightly new form. In certain of his more complicated reaction time experiments, Ach asserts that it is not merely holding the idea of the movement in the centre of consciousness that evokes

the movement, but that in addition to this it is necessary that the self become momentarily identified with the movement to be made. At the moment the self is thus identified with the one alternative, the choice is made, and the action is determined. A somewhat similar statement is made by Michotte in connection with a choice between operations upon numbers as a result of experiments carried on by himself and Prüm.[1] In a second experiment, also on reaction times, conducted with Barrett,[2] measurements were made of the time required to choose between two liquids and to drink one of them. The liquids represented different degrees of pleasantness and unpleasantness. They were tested in advance and designated by letters that should have no associations other than those which developed during the experiment. The observer was to watch carefully what preceded the decision and to determine if possible what was the deciding factor in his choice. In this series of experiments the element of voluntary choice seemed less important. In fact, Barrett regarded the result as proof that choice is made and executed without any peculiar new activity that could be designated an act of volition. Instead, he found that one arranged the tastes as they were learned in order of agreeableness; and, when they were presented, the value on this scale was an immediate guide to the choice. The whole choice was completed when the liquid had been given its letter and place in the series. He finds that the determinants of the act are approximately the same as those we have enumerated above. Michotte[3] in reply reasserts his belief in a pure

[1] Michotte and Prüm, Étude expérimentale sur le choix volontaire et ses antécédentes immédiates, Archives de psychologie, Vol. X, p. 113.

[2] Barrett, Motivation Tracts and Motivation Forces.

[3] Michotte, À propos de contributions récentes à la psychologie de la volonté, Ann. de L'Institute Super. de Phil., No. ix.

act of volition which must intervene in all acts of choice, whether related to action or not, and after the choice is made must again intervene in the execution of the act involved in the choice. He believes that the selection of one from a group of liquids of known value tends to render the process more automatic, and that this accounts for the smaller part played by voluntary choice.

This difference of opinion between Barrett and Michotte is typical of the opposing possibilities in the explanation of a voluntary act. On the one hand, emphasis is placed upon the more remote underlying conditions; on the other, upon the necessity for discriminating between the alternatives by holding in mind first one of the motives and then the other, and making a positive choice between them. On Barrett's interpretation, the motives are effective because they appeal to certain instinctive or habitual and social traits in the man's nature. On Michotte's, the final determinant of action is a force or active element which serves to make the choice and release the act. On the second alternative, the active element is hard to describe, is found by only a few men and by them only on rare occasions. Although prominent in popular discussions, the observation of untrained men, who constitute the chief advocates of its existence, is unreliable. Much of the feeling of will that the popular mind accepts as evidence of a separate faculty is made up of strain sensations, which even Michotte would not regard as an essential part of his voluntary act. Viewed from the practical side, it makes very little difference whether this active element is or is not assumed. All would agree that when the will acts, it acts in the light of the motives; it is an expression of the nature of the man; and that in turn is dependent upon his instincts and training, his immediate purposes and general

ideals. The only question remaining is whether these act directly in the execution of the movement, or whether they act first upon the will, and that in turn determines the act. In view of the uncertainty as to whether the will activity exists and what it is like if it exists, it seems simpler and safer to omit it as superfluous, and to assume that the observed conditions determine action directly. On that conclusion, 'will' is a term to designate the whole man active, or a word used to distinguish between automatic acts and those that imply choice and are controlled by the system of purposes. It does not necessarily imply any new and distinct entity.

**The Will and Freedom.** — This result suggests the old problem of the freedom of the will, and it may be considered here, in spite of the fact that it is at present regarded as belonging to ethics rather than to psychology. At first sight it seems a logical inference that, if man has no will, he cannot be free. This defines the will too narrowly; it would restrict it to the something that we could not find standing between the motives and the act itself. If we regard the will as the sum of the conditions which lead to action or to spontaneous action, or even more generally as the whole man active, the question cannot be disposed of so summarily. From this point of view, the answer as to whether the man is free depends very largely upon how we define 'the man.' We have seen throughout that many of the determinants of all mental action, and particularly of voluntary action, are to be found in his instincts, in the way he has been affected by education and by the society in which he has lived, by his nature and nurture in the broadest use of both terms. If one is to oppose these external forces to the man himself, a good case could be made for the statement that the man is largely determined

by forces outside of himself. But if one make the division between the man and all of these factors, if one take away from the man all that he has learned, all the controlling forces of society, and all of his natural endowments, his instincts and innate tendencies, only a rag of a man would be left; most that is peculiarly himself would have disappeared. It is altogether more satisfactory and truer to the facts to regard these influences as included in the man, to think of him as in part at least the product of his heredity and environment, for this is the man as we know him. To divide the controlling forces into two groups, one external, the other internal, one environmental, the other personal, has never been attempted; and no two psychologists agree where the division would come. Oppose the man as he is, to external forces, and he must be said to control his own acts. They are the expression of the whole man, and he is free to do as he chooses. One may put the solution of the problem in another way by asserting that man is free to do what he desires, but his desires are the outcome of his instincts and environment and over these he has little control. In other words, the question is largely one of classifying facts and of defining terms. The facts themselves are accepted by all.

In practice, acceptance of one theory or the other makes little difference. What one generally does is to think of one's self as a free agent in every respect, and of every one else as rigidly determined by environment and education. It is only when one takes the objective attitude toward one's own acts, that one tries to trace them to their conditions. Probably this assumption works best in practice. The new tendency to regard man as the product of his environment has led to improvement in social conditions, to the recognition that mankind in the mass may be improved

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other means of support that shall make crime unnecessary. In the worst cases, it is a protection to society by removing the criminal to a place where he can do no harm. In any case the idea of vengeance, essential to the older view, plays no part. When it is considered that a large percentage of criminals are mentally deficient, have an intelligence no greater than a child of ten, the modern theory has even more weight. The final outcome of the two theories is approximately the same; but the methods of inflicting the punishment and the attitude while carrying it out are altogether different. On the whole it may be said that the problem of the freedom of the will has been outgrown rather than solved. The present attitude toward the world and man's place in the world leaves no room for the problem, instead of deciding which solution is the correct one.

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# CHAPTER XVIII

## WORK, FATIGUE, AND SLEEP

VERY important for the practical life of industry and even for the health of the individual is the problem of the natural course of work, particularly the length to which work may be carried before the individual becomes incapable of more work, or will suffer injury either immediately or ultimately. In industry, and probably in mental work too, there are limits beyond which one cannot work effectively. Time spent in work would, beyond these limits, much better be spent in rest or recreation; even if one considers only the accomplishment in a given time, with no thought of the effort required, or the ultimate health of the worker.

### WORK

**The Curve of Accomplishment.** — The course of work, or the curve which indicates the accomplishment at different intervals during a period of work, is fairly well made out both for purely mental work and for the combination of physical and mental work which is found in the ordinary factory procedure. At the very beginning there is usually a rapid decline in accomplishment. This is followed by a gradual rise to a maximum moderately early; and from that point there is a decline until just before the end, when a brief rise occurs for the last few minutes. If rest periods intervene, they are followed by a rise, succeeded by a fall at a more rapid rate than before the rest. The duration of the different phases varies with the total length of the

period of work, with the individual, and with the character of the work. In one or two instances of mental work under considerable incentive, there was no appreciable change in the curve. In one in which mental arithmetic was the work used, the decrease during twelve hours of continuous work was only about fifty per cent, and at the end the work was at a rate above that of the ordinary individual.

In the tests of mental work made by Kraepelin and his students, of two hours' duration, the point of highest accomplishment was from fifteen to forty-five minutes after the work began, with a gradual fall to the end. In records of output of work in various factories, the high point seems to be between nine and ten o'clock, when the work begins at eight; then there is a fall until noon; and after the noon hour an increase; with a decrease to the end of the day. As further evidence that there is a somewhat regular curve of capacity in the day's work in the factory, is the time of occurrence of the maximum number of accidents. An accident is due as often to mental as to physical fatigue. Failure to attend or to remember, or lack of judgment in estimating the position of knives or other parts of a machine, is more frequently the cause of an injury than mere physical fatigue. Accidents show a regular increase until eleven in the morning, after which the curve is constant or shows a very slight decrease in the last hour in the morning. It falls after the noon hour to about the same level as in the first hour in the morning, and rises rapidly and continuously during the afternoon.

We have then in the course of work, particularly work that demands mental activity, as almost all work does, a quick fall for the brief period at the beginning, then a gradual increase in accomplishment for a time, followed again by a decrease that is checked only by a short rise at

the end, if the worker knows when the end is to be. A rest of sufficient duration is followed by increased output, and then ensues a more rapid decrease than in the period before the end.

**Analysis of the Curve of Work.** — In the analysis of this standard curve of work it is assumed that the capacity at a given time is determined by a number of coöperating independent factors. The one most frequently mentioned is *fatigue*, which is assumed to increase with the time spent in work. The second, *practice*, counteracts fatigue, since it also increases capacity as work increases in a somewhat regular course. Practice increases more rapidly at first, and then less rapidly. Practice is allied to habit as an adjustment of the nervous system to a new situation, and constitutes what we call skill. It is assumed to reach a maximum at some time, although it is probable that new conditions of work or a new attitude towards work may produce an improvement even after long periods of training. It can be said, however, that practice will make work more easy and effective, that it increases rapidly at first and then more and more slowly as work is continued.

The initial fall and terminal increase are due to a temporary *incentive*. The individual begins with a firm intention of doing his best, and does so for a few strokes. This special incentive wears away quickly, and with it there is often a fall in output immediately after work begins. At the end there is a similar speeding up to make a good showing for the finish. This is not necessarily conscious, but the very fact that the end is in sight serves as an incentive and speeding up takes place automatically, just as the goal in a race calls out a final increased effort. A fourth factor is *inertia*. In most types of work it takes a little time to reach the best speed; and when once started

work is continued at approximately the same rate. This is most evident in the fact that when the work is interrupted by a rest, some time is required to reach the same speed as before the interruption. It makes a shorter rest within limits more effective in restoring efficiency than a longer one.

## Fatigue

**Is Fatigue Real?** — The most important of these factors is fatigue. By fatigue we mean a reduction in the capacity for doing work which comes as a result of work. This definition is open to criticism from the fact that not all work seems to be followed by a reduction in capacity even for doing the same kind of work. Kraepelin explained this as due to the counteracting effect of practice and inertia. Others have held at times that there is no mental fatigue, but that the working individual merely becomes bored, not tired, that the central nervous system does not lose capacity with work. The results of Arai [1] are cited as evidence that mental work may go on indefinitely without noticeable diminution in output. We can probably reconcile the facts adduced in favor of the two views by assuming, as there is good reason to do, that organically work produces a lessened capacity in the organism, but that this is automatically compensated for by extra effort. This keeps the individual working at about the same speed, and possibly with just as few mistakes in spite of reduced physical capacity. The awareness of fatigue is itself an incentive that in many individuals spurs to new effort. In this respect fatigue is just like distraction; and like distraction it may at times over-compensate, so that an individual works even more rapidly when fatigue has set

[1] Arai, Mental Fatigue: Columbia University Contributions to Education No. 54.

in. That fatigue is a real factor is evident from the fact that occasionally a worker will keep up the same speed for a considerable period and then will stop suddenly with what seems to be a collapse. Dodge has shown this in connection with fatigue of eye muscles, and we find some evidence of it in the daily work, particularly in diseased individuals. It must be said, however, that ordinarily the disagreeableness of work after fatigue is pronounced is a sufficient safeguard against carrying work to the point of collapse.

While fatigue is a real accompaniment of mental as well as of physical work, the fact that fatigue does not increase regularly with the amount of work makes it difficult to determine what the condition of the individual is at any time as regards fatigue. One may obtain a general indication from the amount of work done as compared with the average accomplishment, or by introducing some special test or standardized task that shall be closely related to the work being done. The objection to the latter is that one can nearly always under incentives spur one's self to a maximum rate for a brief period, and the test becomes an unsatisfactory criterion of the condition. Dr. Lewis has found indication that the glycogen content of the blood is increased during fatigue; and Dr. Griffitts and the writer have found indication of a lowered blood pressure after severe mental work. It is highly desirable to find some such test of condition that shall be independent of work done, that may be used to determine when the individual has worked enough. On the whole, it seems assured that there is a real fatigue as a result of mental work. Whether one can define fatigue as the reduced capacity for doing work as a result of work or not, is complicated by the fact that diminished physical capacity is

compensated for by greater effort. If capacity is understood as a physical capacity, only indirectly indicated by accomplishment, it may stand. It is at least as satisfactory as any formula that can be suggested.

**The Physiological Nature of Fatigue.** — When we turn to ask what the cause of fatigue may be, we must approach the problem from the physiological side. The first studies of fatigue were made on the muscle and nerve of a frog. If a muscle with the motor nerve that excites it be dissected out of a frog, and hung so that the muscle supports a lever that will write upon a drum, the amount of the contraction will be recorded upon the drum. If the nerve be stimulated, the muscle will contract; as the stimulation is continued the contractions become shorter and shorter until they finally cease. The causes of fatigue in this simple system are found first in the breaking down of the point of connection between nerve and muscle, the end-plate. This is shown by the fact that after the muscle can no longer be stimulated through the nerve, it will still respond when stimulated directly.

Continued direct stimulation of the muscle will completely fatigue the muscle. This indicates that there is a real fatigue of the muscle proper. The nature of this change is due in part to the accumulation of products of degeneration, as can be seen from the fact that after the muscle has stopped acting once through fatigue, it will respond again in almost full amount after it has been thoroughly washed in a dilute solution of salt. There is also exhaustion of the stored nourishment in the tissue, but this seems to come later than the inhibition of the capacity for action, due to the accumulation of waste products. In addition to the waste products that accumulate in the muscle itself, investigations of animals working

as wholes indicate that toxins appear in the blood and may be carried to any part of the body and affect tissues of all kinds. An old experiment of Mosso showed that blood transfused from a fatigued dog to a rested one produced in him many of the effects of fatigue. While later experiments do not altogether confirm the Mosso method, other methods do indicate an accumulation of toxins in the blood as a result of continued work. The toxic effects seem to be diminished or overcome by the secretions of

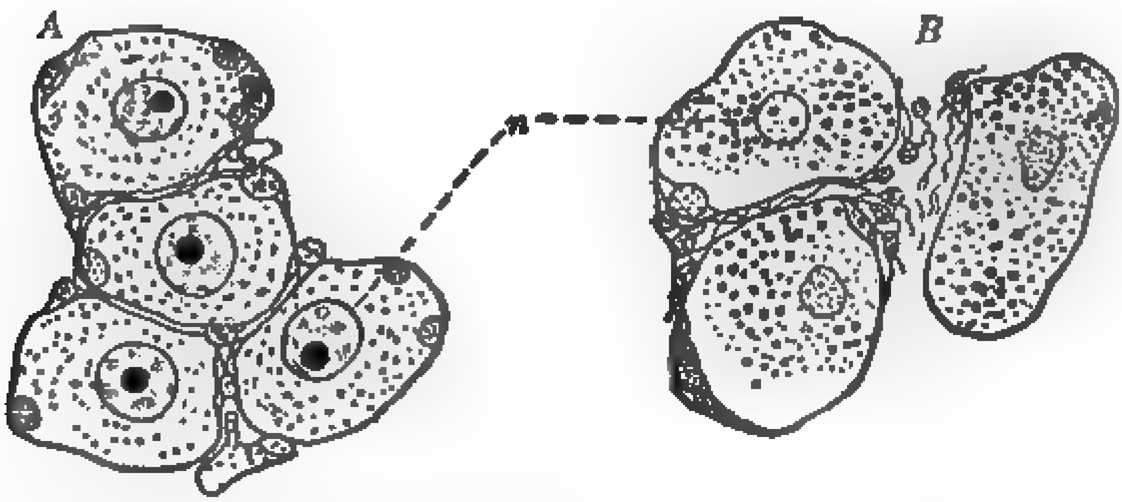


Fig. 97. — Changes in the nucleus as a result of fatigue. (*A*) and (*B*) are both from the spinal ganglion of a cat. (*A*) shows the resting condition, (*B*) a cell after electrical stimulation of its nerve for five hours. The nuclei in (*B*) may be seen to be much smaller and to be very irregular in outline. (From "American Text-book of Physiology," after Hodge.)

adrenal glands. Animals in whom the glands are removed indicate a much greater effect of work, and are also more influenced by injections of fatigue products than are normal animals. This may explain why Dr. Lewis found an increase in glycogen in the blood following mental work. It is possible that the adrenal secretion nullifies fatigue indirectly by increasing digestion and stimulating the liver to an increased secretion of glycogen.

**Fatigue of Central Cells.** — In the body as a whole one more factor is at work, and this is the possible exhaustion

of the nerve cell. Hodge found in a bee that after a full day's work, the nucleus of the ganglion cells was very much reduced in size, and the walls of the nucleus were irregular in shape as if collapsed, as compared with the same cells in the morning. Electrical stimulation of the cells from the spinal cord of the cat for five hours produced much the same effect. These changes in the cell bodies of nerves, the accumulation both in muscles and in the blood of waste products which act as poisons, the exhaustion of the tissues and of the muscles together constitute the physical changes in fatigue. These effects do not all act to reduce the capacity. In the isolated muscle, even, the first effect of fatigue is to produce unusually large contractions. Application to the muscle in small amounts of waste substances from another muscle increases the amount of contraction even with constant stimulus; and the products of the muscle itself have the same effect. Fatigue products first increase the excitability of a muscle, and then diminish and finally destroy it.

**Consciousness of Fatigue.** — On the mental side, consciousness of physical fatigue is marked by sensations of pain or at least of discomfort from the muscles. The lactic acid and other chemicals released by repeated contractions apparently stimulate the nerves of pain in the muscles directly and give rise to the sensations. More general feelings of lassitude may be due to the reduced tonus of the muscles or to the slowness with which muscles respond to stimulation. That there are complexes of sensations which go with the condition we know as fatigue is evident to every one. The immediate sensations are probably to be found in the excitations of pain nerves in the muscles. The remainder is probably an inference from the reduced capacity for action. It has been sug-

gested that mental fatigue is largely an inhibition of action from the distracting effect of these sensations. This may account for part of the reduced efficiency, although, as was seen, distraction also tends to increase efficiency on occasion.

**Mental Fatigue.** — What may constitute mental fatigue apart from bodily fatigue, is not as yet altogether agreed upon. Mental work has always an incidental physical accompaniment. Muscles are always active in some degree. That they are sufficiently active to account for the effects of mental work is extremely unlikely. Certainly mere thinking on an abstruse problem is harder work than a game of golf, for example, which must involve vastly more muscular contraction. Some considerable activity of the cortical neurones must be involved in thinking, but we have only indirect evidence of the amount of change in energy or chemical decomposition involved, and these point in opposite directions. Atwood could find no increase in the bodily metabolism during mental work. Dodge, on the contrary, found that mental work had about the same effect on the circulation as physical work of average intensity. Merely opening the eyes and passively observing a room produced a change equivalent to that produced by lifting a pound weight; and hard reading was found to be the equivalent of a genuflection. Fatigue might be due to exhaustion of the neurones directly, or it might be due to the waste products that are discharged into the circulation and reach the muscles and other parts of the brain. No one has as yet demonstrated the existence of either change. The nearest approach is the discovery by Dr. Lewis of increased amounts of glycogen in the blood as an accompaniment of mental work. The indirect evidence of mental fatigue is found, first in the feeling of lassitude that follows upon mental work, second in the decrease of the

amount of work as time passes, third in the after-effects of long-continued excess of mental work in inducing loss of weight, and the various physical and mental symptoms that accompany what is called a nervous breakdown. Altogether these suffice to indicate the reality of mental fatigue and its general similarity to physical fatigue.

**Bodily Accompaniments of Fatigue.** — If we consider the action of fatigue, mental or physical, in the conditions of everyday life, we must assume that each bit of work has the effect of decreasing the nourishment stored in the tissues, of increasing waste products in the tissues themselves and in the blood, and that if it be muscular work continued for a long time on one muscle it may decrease or destroy the connections at the end plate, and finally exhaust the nucleus of the cells. The first effect of these changes is probably to increase the irritability of the muscle, which increases its capacity. These processes, through the excitation of nerves in the muscles, produce reflexly an increase in the rate of the heart, and of respiration, thus supplying more oxygen to the red blood corpuscles, and a larger flow of blood, which both increases the nourishment at the service of the muscle and washes the waste products out more quickly. After a time the adrenal glands are affected, and these increase the supply of glycogen from the liver and also affect the activity of the circulatory system. For a considerable period these automatically induced processes compensate for the extra work. The capacity of the organism is increased to keep up with the demand.

All these increased activities make a demand upon the reserve; and while the reserve is sufficient to keep the output at a maximum over a long period or even to increase it, it is always at the expense of extra effort. In the long

run there must come an end. Unless the demand is very great, the pain of aching muscles and the other discomforts of exhaustion bring the work to a stop. It is possible under great necessities to continue until exhaustion is complete and sleep or other forms of unconsciousness ensue to put an end to the work and permit recovery to begin. Only very rarely, as in a strenuous military campaign, or the work of a mother with a sick child and the necessity of earning a living, do we see this stage reached in practice. Usually boredom or the unpleasant sensations that accompany fatigue induce one to rest, long before this stage is reached. This is still more the case with mental fatigue. Here the fatigue from one position, if one is writing, or the poor quality of work will make the further effort useless, or will furnish an excuse for turning to a more pleasant undertaking. In mental work, also, the effects of the work seem at times to act as a stimulant. When writing or much interested late at night, work seems to go faster and to be pleasanter than in the earlier part of the day, when fatigue should be much less. That this feeling is not an indication of work without fatigue is evident from the after-effects, the likelihood of a sleepless night and of an incapacity for work the next day. Both mental and physical work and the combination of the two that is seen in industry bring with them a decreased capacity for work, although that may be concealed by the compensating increased activity. Work beyond a certain point is injurious to the individual in that it shortens the period of activity, and shows its effect in the diminished output of the next day. It is a disadvantage in industry for the day-to-day accomplishment.

**Fatigue in Industry.** — Numerous practical experiments have shown that lessening the hours of work, even with no

reduction in wages, is a profitable change for employer and worker alike. The Zeiss works in Jena, numerous munitions factories under the control of the war board in Great Britain, and several cases in America show that reduction from a ten- to an eight-hour day could be made with an actual increase in the output. We have no right to dogmatize as to the optimum working period. Too much depends upon the kind of work, the good will of the workers, and other conditions which are either not directly under control or are not known as yet to make it possible to be certain as to the correct hours for any industry, to say nothing of industry in general. For our purposes, the evidence is sufficient to indicate that there is a limit of working time beyond which it is not profitable to go. Probably this is on the average near the eight-hour day. Slower work, spoiled products, accidents, and the gradual deterioration in the operatives, set a definite limit to the profitable hours of work.

**The Limits of Effective Work.** — It is difficult to determine exactly where the limit lies. The output, we have seen, is no infallible criterion, because when under the influence of strong incentives, work may continue undiminished when fatigue is severe. The sensations and other direct mental signs are also far from infallible. In many cases, again under incentives, one feels that work is a pleasure, when a sleepless night, or a reduced capacity next day, will be the penalty for continuing. On the other hand, one frequently feels little like working when perfectly capable of doing it. One may have a stale feeling in the morning, spend some time in wondering whether one really ought to work that day, or even fear that the work if done will be below standard, and then find when one actually warms up to it that quality and quantity are normal or better.

It would be highly desirable to discover some index of the condition of the individual that might be used by employer, or teacher, or physician, to determine the point where work should stop. Attempts have been made to obtain one. The writer has experimented with the time that one may see a faint light, and has found that the time of visibility changes with the amount of work done. With Dr. Griffitts he recently found indications that there was a reduced blood pressure after mental work. Lewis, as was said, had found an increase in the glycogen in the blood. While the increased glycogen is probably a compensation induced by fatigue, a sufficient amount or a decrease after increase might be made a sign of the point where work should stop. Changes in heart rate, in blood pressure sitting and standing, have been suggested. One must probably find a fatigue index in some of these indirect measures rather than in the output or the sensations, or any of the more direct changes. Long study will be necessary to determine at just what point in the development of any one of these indices, work should stop. Observation of the changes in the sign chosen in connection with the after-effects of fatigue and the capacity for work over a long period must be exhaustive before a useful determination may be made.

**General Rules for Effective Work.** — Meanwhile certain general rules can be given which are helpful in the arrangement of work. One must not expect to avoid fatigue. Fatigue as a group of sensations from the muscles or a feeling of lassitude from long mental work is an inevitable accompaniment of all activity. Only when it becomes excessive is it even a signal to stop. As a tendency to an exhaustion of the tissues even, it is still not injurious, for the deficiency is quickly restored by rest, and use is essential

to growth, or even to health. All that one can ask is that fatigue should be kept within the limits that permit of quick recovery during the same day if possible, and will certainly give complete restoration after a night of rest. How long this shall be for the individual must be determined empirically. Usually the effective working period is well within the limits that are demanded by health. Probably within this effective time are the limits set by the discomfort of sensation, or boredom, or the conventions of the hours that shall be devoted to work. In practice few students overwork, and those who do are the weaker ones. For industry, the hours are set by the length of day most profitable to the employer. This, when all the facts are understood, will be found well within the physiologically determined limits of capacity.

**The Economical Periods of Work.** — The most economical period of work is that in which one obtains all the advantages of continued work without going on to the point of fatigue. It is of course impossible to give any general rules that will apply to all kinds of work and to all people. How much work may be done depends upon the nature of the work and upon the strength of the individual. The fact that one does more after working for a little time than when one first begins holds universally. How long one should continue after the effects of fatigue are greater than the benefits of practice, depends upon the kind of work and the practical necessities for its completion. Fatigue itself is not to be avoided, for the lesser degrees wear off in a short time and are entirely overcome by a night's sleep. The poor work that results when fatigue is too great makes effort unprofitable, and the after-effects in the form of overwork may have such serious results as to put a premium upon avoiding them at all reasonable cost.

**The Best Period for Rest.** — To know how long to rest between periods of work is as important as to know when to stop. Results of experiments indicate that the length of the rest that should be introduced between the periods of work depends upon the length of the previous work and upon the character of the work. The rest should be long enough to permit recovery from fatigue, but not so long as to lose the mental momentum. After long periods of work, two hours or more, the most advantageous intermission is approximately fifteen minutes; for relatively short periods five minutes has proved itself most satisfactory. Longer periods waste too much time, and cause a loss of inertia and of practice that is not compensated for by recovery from fatigue. Shorter intermissions merely cause loss of inertia without any compensating rest. In severe physical work in industry it has been found as important to insist upon proper and sufficient periods of rest as upon sufficient periods of work. In Taylor's first experiment in efficiency management, which consisted in a study of the best methods of lifting heavy pigs of iron, it was found that if the men followed their natural bent, working with the prospect of a bonus, they would work too continuously, and it was necessary to prescribe rest periods which should be rigidly observed, if the most work was to be accomplished in a day. Mental work requires similar rest periods for the maximum performance, but the best periods for the different types and degrees of work have not been determined accurately.

**Change of Work No Rest.** — Several facts that have been suggested by experiments are contrary to the common assumptions of many people. For example, it is believed usually that one may rest through change of work, — that if one has been tired by mental work of one sort it

is not necessary to rest altogether, but by turning to something else one may become rested through the change. The one important investigation on this point indicates that the everyday assumption is not in harmony with the facts. An hour's work learning nonsense syllables, followed by a half hour's practice on mental arithmetic, with a return to the nonsense syllables, rests one no more than a continued period of nonsense syllables. This is on the assumption that learning nonsense syllables is no more difficult than mental arithmetic. If one turns from a more difficult to an easier task, one will of course not be so tired as if one had continued with the more difficult. So far as these results can be accepted, it seems that all sorts of mental fatigue are of the same kind, and that it is not possible to rest one function while exercising another. There is so much in common between the different mental operations that all become tired together. It is possible that the commonly accepted opinion to the contrary is due to the greater interest one may have in a new task. One ordinarily turns from a task only when obstacles have presented themselves or when for some reason the work has become uninteresting. It is possible that the greater interest in the new work and consequent greater effectiveness are mistaken for recovery from fatigue.

**Mental and Physical Fatigue One.** — Very similar is the attitude toward the problem of the relation between mental and physical fatigue. It is generally believed that one may rest from mental work while exercising, but experiments indicate that capacity for mental work is decreased by physical work, if it is too difficult. If one takes a vigorous run or other severe exercise between two periods of the same sort of work, as in the experiments mentioned above, the capacity for mental work is diminished rather

than increased. Here as before the effect will depend upon the severity of the task. If the exercise be mild, one will rest relatively, just as one does during less difficult mental work. In fact, the whole question of work and fatigue is relative, as one never rests absolutely except during sleep, and even then there is merely gain of repair over waste, not absolute quiescence of all functions. The identity of mental and physical fatigue has been demonstrated many times, both that mental work induces physical fatigue and that physical work induces mental fatigue. One cannot do severe mental work effectively after a hard day of physical labor, and experiments show that one is less capable of physical labor after hard mental work. This general identity of mental and physical work and fatigue is being recognized by the physician. A patient suffering from overwork as a result of too much study or worry is no longer advised to take much exercise, but is put to bed or given very little, easy exercise. Of course this does not imply that exercise is not beneficial in health. Exercise is essential to the development and health of the body, and needs no justification. One should not expect to be able to work immediately after exercise, but in the long run the effects of exercise are beneficial.

**Morning and Evening Workers.** — Another interesting result of recent investigations is that there are daily rhythms of capacity for work, that every one has a certain part of the day during which he has greater capacity. According to one authority, men divide naturally into morning and evening workers. The one group are at their best early in the morning, the other group do not reach their full capacity until toward evening, — the amount and accuracy of their work increases steadily through the day It has not been determined whether the difference is in-

nate or the result of habit; but in an adult accustomed to mental work, one habit or the other is always readily demonstrated, even if the individual himself is unaware of it. Evidently one should take advantage of the daily rhythm by devoting the best part of the day to the more difficult tasks. There are also minor ups and downs in capacity during the day which may be confused with rest and fatigue in experiments.

**General Remarks on Work.** — It should be added that the measurements of fatigue upon which these statements rest are derived from ordinary routine work under no particular incentive other than to do one's best. It is certain that a sufficiently strong desire would at any stage have brought the rate of work back to the maximum, at least for a little time. While the amount of work that will be accomplished depends very largely upon the incentive, it does not follow that fatigue is not real and a factor to be considered in the arrangement of the day's routine. The results that have been given hold for the course of ordinary work where the incentive is constant and not particularly strong. If the incentive is increased, the absolute times given would all be increased, but the relative values would still remain approximately the same. There would still come a time when the amount and accuracy of the work would be reduced to a point where work did not pay. Work done willingly and cheerfully under suitable incentives is apparently less fatiguing in the long run than a smaller amount accomplished under unfavorable conditions. One may even agree with James that in moments of exaltation one may perform at a rate far above the ordinary level without permanent injury, and at the same time accept the results of experiments under ordinary conditions as a guide for daily life.

## Sleep

The natural consequence of fatigue, and closely related to it in theory, is sleep. Curiously enough in spite of the frequency of occurrence of the phenomenon, sleep is one of the least understood of the psychological and physiological processes. We know relatively little of the reasons why one goes to sleep, or what takes place when one does go to sleep. As in fatigue, one may develop a circulatory theory, a chemical theory, a central nervous theory, and a general reaction theory, not to mention attention theories and a dissociation theory. It was long held that sleep could be explained by a decrease in the circulation of the blood in the brain, which rendered the brain less capable of action, and so caused unconsciousness. It is hardly likely that the reduction in circulation should be so complete; if it were, there would be no rebuilding of the tissue. Dr. Shepard and others have shown that there is an increase rather than a decrease in the volume of the brain in sleep. The only suggestion of confirmation of the theory is that the walls of the blood vessels of the brain are very much relaxed in sleep, so that waves of respiration are very much greater than in the waking state. This is more likely to be an effect than a cause of sleep.

**Chemical Theories of Sleep.** — The chemical theory is that the products of fatigue accumulate in the central cortical cells and reduce or destroy temporarily their capacity for action. Piéron has results which lead him to believe that a toxin is developed in the blood by loss of sleep which is different from that developed by fatigue. When blood from an animal that has been kept awake for a long period is injected into the fourth ventricle of the brain of another animal of the same species, it shows all of the signs

of sleepiness of the animal from which the fluid is taken. Fatigue products from the muscles do not show the same effect. Piéron's belief is that the toxin of sleep is developed by the action of the cells of the cortex, and might constitute a specific result of mental work for which we were seeking in an earlier section.

**Nervous Theory of Sleep.** — The central nervous system theory was connected with the synapses. In sleep the nerve currents run very slowly, and this indicates increased resistance at the synapse. One early theory was that sleep was due to the withdrawal of the dendrites, in the same way that the amœba draws in its processes when asleep. In animals killed by an anæsthetic the dendrites were retracted in this way. The amœba theory of the synapses has been given up, more because it was difficult to understand why an animal should be aroused from sleep by outside stimuli than because it did not harmonize with anatomical observations. The theory explains sleep, but would permit only spontaneous waking.

**Sleep an Instinct.** — The most recent theory is that sleep is an instinctive reaction to definite sets of stimuli. Several analogies may be developed which are in line with this assumption. The first is the long hibernation or winter sleep of many animals. This seems to be altogether or largely a response to the season, or to temperature and other changes that come with the seasons. Another response of quiescence to a positive stimulus is the death-feigning instinct of many feeble animals, such as the opossum, and the young of the terns. To a strong stimulus, they respond by loss of the capacity for movement, which sometimes is accompanied by loss of muscular tonus. Claparède some years ago and Rivers recently have suggested in slightly different forms that sleep is a response

of a similar character, that serves to make possible the recuperation of the individual. During sleep cessation of all activity, and increased circulation in the cortex, and possibly in other important organs, stop use and supply materials for rebuilding tissues.

To say that sleep is an instinct does not explain it until we can discover what the nature of the reaction may be and what causes it. The stimulus for sleep varies much under different conditions. In most cases it is a response that recurs at approximately the same time of day. In this animals differ widely. Some instinctively respond by sleep to the coming of darkness, others to the coming of day. The difference is altogether instinctive. In man the instinct is subordinated to habit, and the time of approach of the response and the length of sleep vary with the earlier life and occupation of the individual. In addition the immediate stimulus may be presence of feelings of fatigue, but on the other hand too much fatigue may prevent sleep. Monotonous stimuli are also frequently followed by sleep. Absence of stimulation acts as a monotonous stimulus. All stimuli for sleep work best when accompanied by suggestion. If one expects to sleep, sleep is almost certain, unless other circumstances are unfavorable. Excessive fatigue will also finally result in sleep, but can be fought off voluntarily, or under the influence of strong stimuli, for a long time. Animals kept awake by strong stimuli will die after a few days. Loss of sleep is more quickly fatal than is starvation. Fatigue seems to be an inducing condition, and sleep is more and more likely as fatigue advances, provided other conditions are favorable. It seems to be a contributing condition rather than the immediate cause, until it becomes very intense. The final collapse from exhaustion seems to be not quite the same as the normal sleep in

moderate degrees of fatigue. It is more like an intoxication.

The observed phenomena of sleep seem to combine most if not all of the factors that have been suggested as the causes of sleep. Measurements of the course of sleep show that there is a constant increase in the depth of sleep as measured by the strength of the stimulus required to waken the sleeper, during the first hour and a half. After that there is a diminution up to the time of waking. Accompanying this there is a decrease in blood pressure during the first part and a rise in the latter part. On the nervous side, the reduced stimulability has been interpreted as due to an inhibition of the cortical centres; it has also been regarded as a mark of dissociation, for certain of the phenomena of sleep walking and dreams seem allied to hypnotism, and similar processes, that are explained as due to dissociation. One may think of sleep, then, as a reaction in which the central nervous system has its activity inhibited, and the action of the lower centres is checked, which carries with it changes in circulation and respiration and prevents the activity of muscles and glands. The net result is a state in which recuperation is possible. It is also a self-terminating process. As the tissues are restored, and toxins removed from the tissues and from the circulation, the susceptibility of the central nervous system is restored, and any stimulus is more likely to induce the activity of the cortex which brings with it the release of inhibition and restoration of the functions of circulation and respiration.

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# CHAPTER XIX

## THE SELF

In our ordinary life and in much of scientific psychological discussion frequent use is made of the term 'self'. For popular thought the most important part of consciousness and of the world as a whole is found in the 'I.' To it practically everything is referred. It is regarded as the effective agent in most of the acts of the individual, and is the source of most of his emotions. A notion that has so large a share in our mental life must be closely examined and if possible explained. We must, as psychologists, take the same attitude toward it as toward the concrete experiences so far examined. We must seek to determine how far it is open to examination as a mental state, what effect it has on behavior, and how the idea must have developed to the form that it takes at present. It is for us one phenomenon among many, in spite of the central position that it holds in popular discussion. The occasion for the development of the self comes from the practical needs for a distinction between the individual and others, and between the individual and the outside world. To represent these distinctions, concepts have gradually grown up in much the same way that concepts of external things develop, and they are like them in every respect. Each has some mental content, and represents a large number of distinctions and processes not present in the idea.

## The Nature of the Self

**The Occasions for the Self-concepts.** — We recognize not one concept of the self but many, corresponding to the different occasions, to the different ways, in which the outer must be opposed to the inner, and to the different lines of division at which one may be marked off from the other. Three fairly general lines of demarcation may be drawn. One is between the man as a whole, including the body, and the other individuals in society. This is the self as considered in law and in most of the more popular objective discussions. A second line of division develops, as the theoretical interests become dominant, between the body and the mental states or consciousness. Finally, a third notion of the self tends to mark off the more spontaneous and purposive acts, those that are foreseen and consented to, as over against the acts induced by external forces or even by reflexes, — the acts that are intended, from those that are not intended. The first we may call the physical self, the second the subjective self, the third the effective self. It must be insisted that these lines of division cannot be sharply drawn and that they are not consistent from moment to moment. At any particular time we are interested only in one distinction and have no reference to the others. While there are many gross references and many occasions on which it is desirable to unite the three concepts into a single one, they can best be discussed separately at first, and then united so far as is possible in a common notion. In considering these concepts, one must, as in all cases, distinguish between the conscious element used in representing the self, and the meaning, — the thing or processes represented by that concept.

**The Physical Self.** — The centre of reference of the

physical self seems to be the body, partly as it is seen in the field of vision, partly as it is reconstructed on the basis of mirror images and photographs and from the references of friends. The meaning of this physical self is very much wider. It is used to refer to the body, together with many of the man's immediate possessions, — garments and adornments, and an ever-widening group of properties. The 'physical self' gradually comes to be indistinguishable from the 'physically mine.' Houses and lands, friends and position, all of the things that one must struggle with other men to retain, come to form part of the physical 'me.' This physical self derives much of its meaning from comparison with others. One tends to see one's self in relation to others about. The man's picture of himself and of his possessions always involves a comparison with others and with the ideals that these set for his own attainment. The wealth of the individual, rich and poor alike, has increased enormously in the last century, but nevertheless the line is quite as sharply drawn now as ever before, since the relative differences are approximately the same. Similarly, one's opinion of one's physical self in the narrowest sense varies with the individuals with whom one comes in contact. One feels one's self quite a man among small men, while there is a decided shrinking when with men of large stature. One can imagine how different Gulliver's impression of himself must have been when in Lilliput from what it was among the Brobdingnagians. This first concept represents the man to himself as a man among men. It is the self in the most practical, popular sense.

**The Subjective Self.** — The second concept that represents the self as opposed to the body is of much less general application, is of value in fact only in connection with more theoretical problems. The imaginal centre of the concept is

less definite; probably kinæsthetic and organic sensations offer what little there is of actual content. Sometimes there may be a picture of the self, — as the spirit of the savage, or the ghost of the ignorant, — a bodily self with the physical characteristics subtracted, so far as that is possible. This seems relatively rare among psychologists, and others have not reported their results in sufficient numbers to afford much ground for generalization. Usually one is satisfied with the sensations of strain in the head or in the chest as an embodiment of the notion of the self. Its applications, too, are relatively few. One pictures one's self as rising above bodily limitations in ill health; one opposes this self to the sense organs and their imperfect reports of the world. In psychology it is made to include consciousness as opposed to the activities of the nervous system which are purely mechanical. It is also of value in explaining dreams, in which the body seems to be in one place while the spirit is in another. When we attempt to determine to what place sensations are ascribed, there is little agreement even for a single sense. The skin marks the boundary of the self for touch; one thinks of one's self as receiving impressions at the surface and not at some point back in the brain. For hearing and sight the line of division is not so definite. Most refer the sensations to the object in the outside world, and the hearing and seeing self is given no definite place. Organic sensations, particularly the strain sensations that come with effort, are assigned to the self as opposed to the body. On the sensory side, then, while every one would assert that mind and body are to be distinguished and that the 'I' is on the self side, the line of division is very vague. In most cases one would deny any of the seats that might be suggested for the processes without being able to assign a better. It would not even be a matter of agreement that

the self in this sense included all of consciousness; nor, granting that, exactly how much it did include. Obviously, this second concept corresponds to a real need in psychological discussions, but equally obviously the concept is not at present and probably cannot be very clear cut, either in its image or in the limits that it makes between self and not-self.

**The Active Self.** — The third concept of the effective or dynamic self represents a more real need both in psychology and in practical life. In nearly every one of the processes we have considered, something has been left unsettled in the explanation. The final presupposition upon which explanation of each was based had many similar elements in each of the processes discussed, and different theories sought an explanation of each of the more important processes in terms of some other. In attention, first, it was seen that there was a final factor which was characterized by the feeling of effort reduced in part to sensations of strain, the condition of which was found in social pressure. The resulting attention was classed as voluntary. The same factors were at work in the control of associations, and were later seen to be factors which, when present, increased the rate at which associations were formed. In the emotions it was found necessary to assume some tendency toward an end, some purpose that must be aided or hindered before emotions could appear. Finally, in action it is necessary and usual to distinguish simpler movements, that come under the head of reflex, instinct, or habit, from those that seem to depend upon wider knowledge and more fully conscious purpose. Each of these has something in common. Voluntary attention was explained by the social instinct; emotion seemed dependent upon purposive activity of some sort; action is commonly

explained by attention to an idea or an end. Nor is the interrelation limited by these statements. Many authorities would explain movement in terms of feeling; others, feeling in terms of movement; still others, attention in terms of movement; others again, attention in terms of feeling, just as feeling and movement are explained by some in terms of attention. The common elements in all of these processes and the last term in the explanation of each are often called the self.

The self in this sense has practically no new mental processes to represent it. One may think of it equally well as the physical self or a ghostly self. The mental content is indifferent to the meaning. The only sensational element that is at all a general concomitant is the mass of strain sensations so frequently mentioned as constituting the feeling of effort. These are taken to serve as an indication of activity rather than as a direct revelation of the self. In the attempt to analyze the factors which determine the course of this activity, we again have little to say. Our first reduction to social pressure proves, when seen in the light of our knowledge of instinct, to reduce largely to a social instinct guided by knowledge obtained from the society in which the man has lived. The original instinct we found in discussing emotions developed into a system of ideals, and these, as they became more active, constituted the purposes of the individual. The study of action offered no new contributions to our explanation; action was an outcome of ideals and purposes acting in selection. There was found no new impelling force, nor even any new quality or mental state. Study of the self adds nothing new. As a man studies his own self, he is aware of the fact that he is acting or deciding, but he gets almost no light as to what the process consists in. If he studies another, he can

trace certain factors that seem to play a part in making that individual decide as he does, but neither observation of one's self nor of another can show directly what the determining activity is. Curiously enough, tracing the conditions tends to discover the basis of the activities that are believed to be peculiarly characteristic of the self in society. The more intimately personal the act, the more objective are its conditions, the more external the forces that bring it about.

In each of these more active processes, one feels that there is something that must be explained in terms of factors that cannot be definitely formulated. The tendency is always to bring in some other simple process as the basis of the explanation, hence the reference from one process to another among mental states. But, when one sees that one can complete the circle and come no nearer the explanation in one group than in any other, it is obvious that going around the circle has not furthered the explanation. Two alternatives remain open. One may assume either that some highest process controls all the others, or that there are common elements in each; and then seek to determine what they are. The popular mind takes the first of the alternatives, — assumes the self as a prime determinant, and makes it the final force in all spontaneous action. Since, however, this is in reality no explanation but merely a tagging of the facts that are to be explained, it is more important to determine the elements common to each. This we may find in the developed ideals and purposes, which in turn are to be referred, first to instincts, then to the ideals of society taken over by the individual largely by virtue of the social instinct — the instinct to seek approval — and then tested and confirmed by his own individual experience. If other factors enter, they cannot

be traced, either in the introspection of the agent, or by a study of the behavior of others. In the complexity of the conditions that act upon the individual we are not, however, in a position to assert that no others are effective at any point.

**The Social Factors in the Self Concept.** — These three concepts of the self tend to fuse into a single one in which something of each is retained, and are more or less harmonized into a unitary whole. The representative self has something of the body, something of the mental as opposed to the bodily, more of the strain processes that mark it as active. The concept is ordinarily employed to distinguish between the self and society, between the 'I' and the 'You,' or, objectively, between the characteristics of the different individuals with whom I come in contact, who must be used in the accomplishment of my ends, or who use me in the attainment of theirs. With this there is a marked effect of the life in society. Both the static and the dynamic features of the self are appreciated only in terms of others about. One has an idea of one's own peculiarities only in comparison with others. One's notion of one's self as a whole is largely an image of the self as it is reflected in the consciousness of others. When a man is among men of smaller attainments, or smaller possessions, he expands; when he is with men of larger accomplishments or reputation or possessions, he shrinks just as evidently. Much of this idea of the self depends, not upon actual ability and possession, but upon the imagined attitude of others. A man becomes accustomed to act as if he were of more than ordinary importance, society takes him at face value, and he may go for years or even through life without having the notion corrected either for himself or for others. On the other hand, a few rebuffs

to a sensitive individual will repress his self in his own eyes and prevent any self-assertion. If he has high ability, it may go for years without being discovered. Society makes its judgment of a man in part from his own actions; and these in turn depend in some measure upon the estimate he thinks society puts upon him. The process is a cyclical one. The individual's estimate of himself is what he believes to be society's estimate of him. On the other hand, society's estimate of the man is very largely colored by his estimate of himself and his consequent bearing. The way in which the individual pictures himself and the estimate of his personal capacity are largely derived from the attitude of society toward him, just as many of the forces that control his active life are merely an expression of the society in which he lives.

**The Emotions of Self.** — The activities and processes that develop the notion of self are found very largely in the emotional group. What we called the more complicated emotions, those which come from the interaction of the purposes of the individual with the environment, are largely social in character. The opposition is most often from other men, and the emotion is usually ascribed to an expanding or shrinking of the self. In fact, in much of our daily life, the only reason for making use of the notion of the self is to picture the origin and the immediate source of the emotion. We are concerned with the self only in moments of struggle and the consequent success or defeat. In periods of quiet contemplation of external objects or even in the unhindered manipulation of things, we are little aware of the self. With opposition, particularly from other men, the complex of emotions comes into play. We have the self-assertion of effort, the elation of victory, the self-depreciation of defeat. That these emotions are

always of a social character is seen in the fact that when one performs a difficult feat when alone, there is always a thought of what some one else might think; and the pleasure in the success comes largely from the background of realization that it is better than could have been done by one's rival. The onlooker is always present in thought if not in reality, and the resultant emotion is determined by the way the action would be viewed by him rather than by any absolute standard.

These self-regarding emotions constitute the core of the idea of the self. The character of these emotions seems to depend upon the relation between the ambitions of the individual and his actual accomplishments. James puts it in the statement that self-esteem equals success divided by pretensions. When pretensions are large, success small, self-esteem is slight; as success grows or ambitions diminish, self-esteem or self-complacency is increased. Self-esteem, too, is only affected when success or failure comes in some field in which the ambition of the individual lies. A scholar may very well content himself with little of the worldly goods, may even regard wealth as somewhat vulgar, since he has never set himself towards its attainment. The wealthy man of affairs returns the compliment by saying he can buy the services of a scientist much more cheaply than he can the advice of a financial expert, — that learning is a drug in the market. Each is satisfied with his own position, with his own self, as he has never attempted to extend the self in the field of the other. But when men of affairs come into rivalry in the same field, the self of the one is humiliated as the other attains what he has himself sought.

These emotions, or the conditions that lie behind them, not merely determine how the individual shall regard

himself, but also play a very large part in deciding the degree of effectiveness of the individual. The way in which the self is regarded determines the attitude toward the problems of life, and this in turn is an important factor in the success or failure of the individual. The character of the individual, viewed either from within or from without, is closely related to his self-esteem.

The man who has succeeded and lacks a sense of proportion or the saving sense of humor becomes self-conceited. He can no longer remove his mental gaze from contemplation of his own capacities and of past successes, nor can he avoid expressing this appreciation of himself, nor conceal his expectation that others will express their appreciation of that position. A child who is always the centre of the approving household develops an exaggerated notion of his own importance, and his early success in business or scholarship not infrequently sets an attitude of self-satisfaction that cannot be disturbed even by later failures and rebuffs.

More striking is the expectation of failure and consequent lowering of ambitions that comes with crushing defeat. A man of middle age who suddenly finds his system of ambitions thwarted and all of the accumulations of previous successes swept away, seems to lose not merely all of his ambitions, all of his self-respect, but also the capacity for forming new purposes. The self disappears or is profoundly altered with the despair that follows. Numerous members of the drifting colonies of ne'er-do-wells of our large cities have been brought to their position by some such catastrophe. The man of means who, at first confident, self-assertive, and persistent, loses his wealth through some mischance, and fails in the first few efforts to reëstablish himself, comes to mistrust himself and all his ventures, — becomes vacillating. Others lose confidence in him, and

he either decides that nothing is worth while, takes a carefree attitude toward the world and attempts nothing, or falls into despair and, while his ambitions are retained, gives up hope of realizing them. In brief, the system of ends feeds on success and grows as each ambition is realized, but shrinks and finally disappears with repeated failure. Happy is the man whose ambitions are not too different from his capacities and to whom environment is sufficiently favorable to permit the realization of ambitions in sufficient degree to give constant encouragement, without too great expansion of the notion of his capacity and importance.

The self is in this sense an outcome of the emotions which arise when the system of aims receives a shock, or attains one of the subordinate steps toward an end or the end itself, although the emotions are in many cases referred to the self as the cause. At bottom, the two processes are probably one. The self is a concept that serves to explain both the emotions that originate from the progress toward ends and also the purposes themselves. Here again we seem to be going around in a circle. Where we seek the self, we find only expressions, only processes that have needed a self to explain them, rather than a real self. On the other hand, when we seek the explanation of certain of the more fundamental emotions, we are said to discover evidence of the self, or at least a reference to the self. In other words, wherever we seek the self, we find something else, but whenever we are seeking an explanation of spontaneous or purposive action, we find that we need, or at least wish we might have, a self.

To bring together the results of our investigation, the self is a group of concepts originally developed to represent the different lines of division between the man and others, between the mental and physical processes, and between

the more mechanical and the more spontaneous forms of action. The different concepts are frequently fused, at least in part, into a single concept which becomes representative of the system of purposes as they control actions, which gives rise to emotions and serves to designate the directing forces in the more complicated mental processes. This concept is the point of reference for all our self-regarding ambitions, it is the self we are depressed about and the self that we exult over. Nevertheless it must not be assumed that something corresponding to this self need be found by introspection. Just as space, regarded as a concept, was needed to explain certain of the ways in which we saw objects and the possibilities of movement, so the concept of the self is merely a way we have of representing to ourselves the immediate facts found in the emotional and the active life, in the life of decision. Examination gives us nothing more than does contemplation. We can analyze the way in which we perceive space relations into certain elements, we can show why we need the concept of space, but we do not expect to find anything more by any means. Similarly with the self, we can point to certain strains as usually present when we think 'I,' we can show why it is needed as a means of making certain distinctions, but we should not expect to find anything more by observation or experiment, — and we do not.

### The Continuity of the Self

**Self-identity.** — Extensions of this empirically derived self-concept or other related concepts have been developed to solve certain of the more theoretical problems of psychology and metaphysics. One of the simplest of these is to answer the question of how the continuous, ever-changing series of mental processes can all be referred to the same

self, are held together in a continuous stream, and are regarded as states of the perceiving self. As a matter of fact, the practical man is never bothered by this problem. In observation he is concerned only with the things that are meant. It is only in recognition that the fact that he has seen a thing before is important to him, and even then he is more interested in knowing that the object was in a certain place at a certain time than in the fact that he saw it there. The different experiences are held together as parts of a single whole by the interrelations that make recognition possible, that make it possible to refer each experience to a definite position in the series. This fact of reference is immediately observed. When the self-concept has developed, the theorist makes that the point of reference, in spite of the difficulty in seeing how an actual substantial something apart from the experiences could hold them together. If by the self we mean the experiences themselves as interrelated one to the other, the notion offers less difficulty.

**The Unity of Consciousness.** — Similar theories have suggested that the fact that all of the mental states form a unity at any moment can be explained in terms of the self-concept. Again it must be insisted that what is or can be noticed is the unity, so far as that exists, rather than an ego. A self in addition to the states would not give them unity. Rather must the unity come from the interconnection of mental states, the subordination of all to some single one that is the central point of attention. As has been seen frequently, many processes, some corresponding only to partially aroused association paths, coöperate in constituting any single experience. In part this unity is explained by the nervous system, in which many neurones are always aroused together and the action of each produces a spread

of impulses to all of the others; in part it is to be referred to the interrelation of what might be regarded as single elements in the formation of concepts and meanings, the real mental units. In any case the unity is within the mental states, not a unity that comes from without through a connection with some single thing. In both of these cases, as in the more empirical active and emotional processes, the facts are to be found in the continuity and unity of mental processes; the self-concept is developed or introduced to explain them. It is merely a method of picturing, not an actual experience. Here the concept is even less satisfactory as an explanation than it was in the preceding instances.

In one respect the more cognitive processes which are explained by this more passive type of self may be combined with the more active discussed above. The system of purposes which was seen to be the deciding factor in deliberate action, and to determine the character of the emotions, is closely bound up with the system of knowledge. Given the instinctive basis, each experience modifies that instinct, and gives it definite content at the same time that it aids in the construction of our system of concepts and prepares the way for recognition and for meaning. In this way the two groups of systems become closely interwoven and are probably for the most part merely different expressions of the same fundamental unity. When active in the control of perception and reason, we term the result the cognitive processes; when acts and emotions are involved, we speak of purposes. All education influences each system, though in different degrees. The system of purposes closely determines the acquisition of knowledge and the use made of it in memory and reasoning, while the knowledge obtained has its effects on the formation of purposes. It is the close

interrelation and dynamic interaction of all parts of experience that really give a unitary character to the acts of the individual, determine his intellectual interests, and make possible the continuity of recognition and of meaning.

## Dissociations of the Self

**Dissociations of Personality.** — That this interrelation of all parts probably has a physical basis is evident from the fact that in certain abnormal individuals the unity of memory or knowledge and of purposes may be broken up into two or several systems, each of which acts alone to produce all the capacities of a whole individual, but which differ in the characteristics of each of the partial personalities. The cases of alternating or dissociated personality offer much of dramatic interest, which cannot be treated here. A person who may be in fair health will suddenly find himself in a strange situation, with no memory of anything that has happened before. In one case even the most rudimentary knowledge of simple things was lost, and some days were required for the patient to recognize simple objects, and still longer to learn to speak. For a long time this second set of experiences remained cut off from the old, then finally the patient awoke again with no memory for recent events, as if he had just waked up into the first set of experiences. In most cases the second self comes into being with a portion of the original memories and experiences of the old. There is a dissociation of the old into two or more parts, rather than a development of an entirely new series. The patient suddenly wakes in an unfamiliar environment, with no memories of where he may be or of recent events, but with full command of language and the ability to interpret the objects about. After that the different personalities or groups of experiences will alternate. The time occupied

by one self varies greatly, as does the occasion for the change from one to another.

**Characteristics of the Partial Selves.** — If we relate the characteristics in which the selves vary, and the marks that distinguish them one from the other, to the facts that have led to the development of the self-concept, we find that practically all of them may be closely paralleled. One element in the consciousness of self is the persistence of various organic sensations. One feels at home in the body, if we may indulge in metaphor, because the strain sensations are constant from one time to another. Ribot reports some cases of split personality in which the organic sensations were changed, and suggests that the change might in part have accounted for the alteration. Much more important is the break in the line of association, the inability to recall an event in one state which has occurred in another. The train of memories seems to be broken off sharply when the personality alternates. Everything that happened in one state can be recalled in that state, but all the experiences of the other state are lost. There is, furthermore, no recognition in one state of the objects seen in another. The associations that connected them originally are completely broken, while the associations within each group persist. It is this characteristic that gives the name of dissociated personality. In the dissociation there seem to be peculiar divisions of the original self. In the Beauchamp case, reported by Dr. Prince, one self kept the knowledge of French of the original, while the others were entirely without it; and other acquirements seemed to be assigned to one alone of the personalities.

Not merely are the acquirements differently divided, but the active and emotional characteristics seem also to vary. One self will be highly conventional in action and desires,

will respond very quickly to social instincts, the other will be entirely arbitrary in action. The difference may approach that so vividly pictured by Stevenson in his story of Dr. Jekyll and Mr. Hyde. The purposes of the two selves are different, as are also the memories. This is in accordance with our explanation of the development of ideals by the action of the accumulated experiences. When the systems of knowledge divide, the control exerted by each of the two sets of ideals or purposes is exerted differently according to the components that make it up. Dr. Prince suggests that in certain cases the instincts as well seem to be divided. One self will take most of the tender and benevolent instincts, the other most of the aggressive, the rebellious, anti-social instincts. Where one self will be painfully conscientious and considerate of others, the second will be altogether selfish and indifferent to the ordinary family and social welfare. With the break in knowledge, there goes a corresponding sudden alternation in the effective self. The individual shows different emotions, is differently controlled in action and in thought. Aside from the fact that both selves are still in the same body, they are essentially two individuals, two selves. There is no memory or recognition of events that occur to the other self, there is no consistency of action between them, there is no continuous self-consciousness from one to the other. Both the theoretical and practical characteristics of the two selves are altered.

**The Phenomenon of Dissociation.** — If we attempt an explanation from the physical side, it would seem that the various effects upon the nervous system are retained and organized into systems; that these systems, while ordinarily acting as units, may by certain shocks be dissociated along somewhat definite lines of cleavage that also develop as a result of the formation of distinct systems. When the

break comes, we have each system or group of systems persisting, but with no bonds of connections between them. Each system continues to act alone, and to control the responses through the persistent nervous connections, guided by the wider series of partially active neurones. In most cases certain of the more frequent nervous activities are common to the two systems, but this shows itself only in the persistence of the nervous correlates of more general concepts and ideas, to which each of the new experiences may be referred and be understood, with none of the more specific references that constitute recognition. The normal self has as its correlate on the physical side a complete system or system of systems, from all of the more important parts of which impulses may pass to awaken all of the other parts, — a system that embraces and unifies many lesser systems, all of which are connected. So long as this system remains unbroken, memory is continuous, memories from all parts of the life may be recognized, and the actions are sufficiently controlled to be consistent. That this is the basis for the characteristics that we have regarded as constituting the peculiar condition of the self is evident from the fact that, when this complete system is broken into two or more groups of systems, two or more selves make their appearance.

**Hypnotism and Other Forms of Dissociation.** — Not only does dissociation arise spontaneously, but in many individuals it may be induced at will. If, for example, a patient be asked to keep attention continuously fixed upon some one object, he will pass into a cataleptic stage, his muscles will stiffen, and he will gradually to all appearances become unconscious, and in the higher degrees of the resulting abnormal condition will show many of the phases of the dissociated personality. The state is much more

readily induced if the patient remains passive and is told from time to time that he is going to sleep. When most completely hypnotized, the patient is highly suggestible, will do anything that he is told to do, may even be made to take on different personalities. On waking there is ordinarily no memory of what has happened during the hypnotic state, although when hypnotized again, the person may recall the events of this period. The close relation between this and the phenomena of the dissociated self is indicated by the fact that change from one self to the other often can be induced by suggestion in the hypnotized state and that when hypnotized in one state, that self will recall events experienced in other states. In many diseased conditions there is evidence that partial dissociation of these systems may take place and may be responsible for the disease. Hysteria is largely, if not altogether, due to a breaking away from the whole of some one of the systems. This may not be large enough seriously to disturb the higher coördinations of the self, but does prevent the larger system from receiving impressions from certain sense organs connected with the dissociated elements, and may also cause a paralysis of the muscles that are either permanently or temporarily united with those dissociated elements.

## The Self as the Whole Man Active

**Consciousness and Subconsciousness.** — Numerous theories have suggested that the self is seldom completely united, that there are always larger or smaller groups of experiences or memories which are independent of the larger system. Thus, Freud, as we have seen, explains dreams and many of the accidents of daily life as well as the witty sayings of the normal individual by the fact that he has an organized complex of elements, which usually

contributes little to consciousness but which on occasion will be excited and when aroused open new possibilities for good or evil in the individual. This detached complex is frequently said to have all of the elements of the normal or total self, to have desires of its own, to do thinking for itself, — in fact, to constitute a true self, which is also regarded as having a kind of consciousness. Many facts point to the presence of these complexes, and the assertion that a definite consciousness attaches to them raises many questions as to what our ordinary consciousness may be, upon what it depends. It must be granted that these subconscious systems give rise to many, if not all, of the effects of the complete system. We could personify them as readily as we do the experience of many other individuals. The only test of consciousness from the inside, however, is the personal test — that we are aware of it in introspection — and by definition this subconscious does not belong to that class.

However, so many of the determinants of our personal consciousness are not themselves directly conscious that the difference may not be important. Of all of the myriad activities in the nervous system, only a few can be known at any moment; and, as has become apparent from the study of meaning and related processes, no one of these is consciousness, of and for itself alone. It must always be grouped with a number of other activities, if consciousness is to result. Even then consciousness is limited, in most cases, to the things referred to or meant, rather than to the elements that are supposed to carry the meaning. Each group of nervous elements may by its activity contribute to the consciousness of the total, but the conditions of consciousness must still be regarded as obscure. The most that can be said is that of the different systems which

are found within the nervous system at any one time, the largest and most active is accompanied by consciousness. The others are either completely suppressed, as in the case of the complexes of the subconscious or unconscious, or the minor systems contribute only in some slight degree to the total consciousness. Consciousness seems to be determined by or to accompany the activity of a system of nervous elements, connected by virtue of acting together in various systems of experiences. How many elements may be included in what corresponds to the centre of consciousness, and how far less central elements can play a part, no one can say. It can be asserted with assurance that even the most central features of consciousness correspond to the action of many neurones, show the effect of many experiences, and represent even more. Where the limits are to be drawn is not to be confidently stated.

**The Self and the Individual.** — Very little of the nervous action is really accompanied by consciousness, although a very large part of that activity has an effect upon consciousness. Much the same statement may be made of the functions of the individual, as we deal with him in psychology and everyday life. We know that he remembers and recognizes, that he perceives objects, and reaches conclusions, that he feels and chooses; we can even trace many of the conditions of these different operations, but he himself is conscious of little more than the outcome, — the causes are not revealed in consciousness. There is no occasion, then, to spend much time on the question whether some of the hidden complexes of neural activities are accompanied by consciousness, when we know so little of the causes and effects of the highest, most fully revealed consciousness.

A close analysis of self-consciousness gives as little re-

ward. One has certain concepts which are represented by more or less definite imagery, but again the important factor is not the imagery but what the imagery represents. This is our notion of the whole as active, of the processes that direct our thoughts and acts, a continuous experience, with the possibility of referring from any part to any other. All these are involved in the self idea, but are not all conscious at any time. The consciousness of self is seldom present and is of little importance when present, the self as the whole man active, as the unity and continuity of experience, is fundamental. It must be emphasized that this is not a single experience among the other experiences, it is not something of which we may become immediately conscious; on the contrary it is the man with all of his experiences and activities viewed as a whole.

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